A Forest Water Quality Literature Review

Abstracted Articles Describing The Water Quality Effects of Forests and Forestry

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Introduction
This 95-page document contains references and abstracts of more than 286 scientific articles particularly relevant to forest water quality. I have made an effort to compile a pertinent body of material, germane to forest water quality and useful as a starting point when searching for forest water quality facts and science based information. The entire document may be searched by keywords using the "find word" options available within the Edit menu of the Adobe Acrobat PDF File Reader. Simply insert a word or phase of interest using this mechanism and then use the "find again" menu item to move sequentially through the document accessing references and abstracts containing the word or phrase. In addition, citations may be copied and entered into the Google search engine to facilitate locating full copies of articles via the Internet.

Citations are listed alphabetically by the lead author's last name and begin below.

1. Adams, Paul W.; Beschta, Robert L.; Froehlich, Henry A. Mountain Logging Near Streams: Opportunities and Challenges. in: Proceedings, International Mountain Logging and Pacific Northwest Skyline Symposium; 1988 Dec; Portland, Oregon. Corvallis, Oregon: 153-161.

Mountain logging near streams has come under increasing scrutiny and control in the Pacific Northwest as the unique functions and benefits of streamside areas have become more apparent. These characteristics include diverse and productive plant cover and forest stands, heavy shade, abundant large and fine organic debris, control of erosion and sedimentation, and significant fish and wildlife habitat. Logging near streams can alter many of these characteristics and produce a variety of resource effects. Among the key challenges related to logging near streams are habitat improvement, integrated resource and operations planning, the development of site-specific and prioritized streamside management practices, and evaluations of logging feasibility and environmental trade-offs. Skills and abilities in communicating and applying appropriate technologies and approaches to meet these challenges will become increasingly important.

2. Ahtiainen, M. Effects of Clear-Cutting and Forestry Drainage on Water Quality in the Nurmes Study. In: Symposium on the Hydrology of Wetlands in Temperate and Cold Regions; 1988 Jun 6; Joensuu, Finland. ; 1988; Volume 1.

The water quality and runoff of six small forest brooks have been studied since 1978. All brooks were investigated in their untouched state for nearly five years, after which clear-cutting and forestry drainage were both carried out in two different ways and to two different extents on four of the basins, leaving two undisturbed throughout, as control basins. Water temperature, colour, and chemical oxygen demand values increased immediately after clearcutting. Large scale cutting on peat soils increased the 3-year mean leaching of organic matter by 73%, the corresponding increase after cutting on mineral soil with a protective zone left along the brook being 23%. The large-scale cutting on peat soils significantly increased the rates of leaching of total and phosphate phosphorus, the first year values of 55 kg/km2 per year (tot-P) and 33 kg/km2 per year (PO4-P). These rates rose still higher in the second year to 75 kg/km2 per year (tot-P) and 55 kg/km2 per year (PO4-P), but decreased to 47 kg/km2 per year (tot-P) and 28 kg/km2 per year (PO4-P) in the third year. The phosphorus was predominantly in soluble form. The smaller-scale cutting on mineral soil increased the load of total phosphorus by one third in the first two years. In one of the two basins where both clear-cutting and ditching were carried out, the annual load of suspended solids increased 4-fold in relation to the control value the first three years. Ditching of the soil in the other basin, which is more sensitive to erosion, caused an increase in suspended solids to a level 17 times higher than during the calibration years.

3. Airry, Robert R. Water quality protection in forest management: are best management practices working? In: Callaham, Robert Z.; DeVries, Johanna J., Technical Coordinators. Proceedings of the California Watershed Management Conference; 1986 November 18-20; West Sacremento, California. Berkeley, California: Wildland Research Center, Division of Agriculture and Natural Resources, University of California; 1987 Feb: 55-62.
Note: need/ ks.

4. Alabama Forestry Commission. Alabama's Handbook of Water Quality Best Management Practices for Silviculture. : Alabama Forestry Commission; 1989. 29p.

The relation between forest management practices and water quality is extremely complex. Many elements--people, resources, expertise, and economics--must be considered in achieving a realisitc balance between society's need for forest resources and that of water quality. The forest resource is vital to the welfare of the people of Alabama and significant in the U.S. economy. Timber lands comprise a major portion of the Alabama land base. About 65 per cent, or over 21 million acres, of the State's 32,678,000 acres is forested. Alabama's commercial forest lands are among the most productive in the United States. As of 1982 this productivity meant a $2.25 billion contribution to the economy of Alabama, including the provision of 60,700 forestry-related jobs. Other beneficiaries of the Alabama forest resource include the millions of American consumers, who use wood products at a volume expected to double at the end of this century, and those outside the State whose jobs depend at least in part on Alabama forest products (e.g., construction trades, paper converting, printing, etc.) The actual ownership of Alabama forestlands has a broad population base. Some 170,000 "small private" forest landowners (holdings of less than 500 acres, by definition) account for 75% of Alabama's timberlands. The rich contribution of Alabama's forests to the people of the State and the nation is based on the economic feasibility of commerical forestry on this land. Obviously, the continuation of sound commercial forestry is crucially important to the people of Alabama, including those not directly involved in the forest resource. In addition to forest management techniques which have already brought Alabama forests to a high degree of productivity, new legal requirements necessitate consideration of water quality as well. Best Management Practices (BMPs) are guidelines recommended to encourage the use of forestry practices which are economically feasible for the private forest landowner in Alabama, and which at the same time, will control water pollution from nonpoint silvicultural sources. Alabama's timberlands supply raw materials to support a substantial forest products industry--the second largest manufacturing business in the State. They produce raw materials necessary for the production of essential commodities. At the same time, these lands provide scenic beauty, recreation, wildlife habitat, and protect our watersheds. The following guidelines support the basic concept of multiple use, and recognize its role in the continued promotion of responsible stewardship of the State's forest resources. The success of forestry programs within Alabama depends on mutual cooperation and trust among landowners, industry, environmentalists, wood producers, regulatory agencies, governmental officials, and the general public. All have an interest in good forest management as it relates to water quality.

5. Anderson, H. W.; Hoover, M. D.; Reinhart, K. G. Forests and Water: Effects of Forest Management on Floods Sedimentation, and Water Supply. : USDA Forest Service; 1976; General Technical Report PSW-18. 115p.

From the background of more than 100 years' collective experience in watershed research and from comprehensive review of the literature of forest hydrology, the authors summarize what is known about the forest's influence on the water resource, particularly the effects of current forestry practices. They first examine the fundamental hydrologic processes in the forest. They then discuss how water supply, floods, erosion, and water quality are affected by timber harvesting, regeneration, tree planting, type conversion, fire, grazing, and the application of fertilizers and pesticides. They consider and present the special problems of fire-prone chaparral, phreatophytes, wetland forests, and surface-mined sites. Finally, they assess potential increases in water yield that might be achieved by forest management in each of six major forest regions in the United States and venture some predictions about future management of watersheds. Nearly 600 references provide a fairly comprehensive overview of the literature.

6. Anderson, Henry W. Sedimentation and Turbidity Hazards in Wildlands. Watershed Management; 1975 Aug 11; Utah State University, Logan, Utah. : American Society of Civil Engineers; 1975 Aug: 347-376.

Results of current and older studies are reported to illustrate how sedimentation and streamflow turbidity hazards can be evaluated. Indices of sediment hazards, production coefficients that alter those hazards, and techniques for appraising sediment potential, both in terms of suspended sediment and in reservoir deposition, are applied. A system for selecting sediment and water quality units and defining a unit area on which water quality might be monitored and sedimentation predicted is developed. Five subsystems characterize the basic sediment producing potential of meteorological, geologic, topographic, vegetative and land use condition. Another subsystem can be used to adjust to the full 81-year records sedimentation measured during different periods. This was done by "normalizing" the effects of streamflow, snowfall, elevation, and latitude in relation to rain-snow frequency. The effects of forest fires, conversion of steep forest or brushland to grass, and unstable stream channels are explored for their effects on sedimentation. Professional foresters and engineers are urged and should be able to use such information as part of their professional capacities. Good management dictates it, the public is demanding it.

7. Anderson, M.; Gehrke, C. National Forests Policies for the Future. Volume 1: Water Quality and Timber Management. Alexandria, VA: Global Priniting, Inc.; 1988; The Wilderness Society. 61p plus appendices.

The impact of forestry practices on the nation's water resources is a matter of long-standing concern. Over time, the focus of public attention has shifted from floods and streamflow to the protection and enhancement of water quality and fish habitat. Surface erosion, mass soil movements, and sedimentation caused by logging and road building are among the most highly visible and controversial dimensions of the water quality issue. This paper examines conflicts between timber management and water quality in the national forests, with primary focus on the northern Rocky Mountains and the Pacific Northwest. Particular attention is directed to forest lands that are characterized by steep and unstable terrain and that possess valuable watershed resources. Much of this land is likely to be uneconomic for logging, and the erosion and landslides that occur after the land is disturbed are certain to create serious environmental damage. Based on case studies and a careful review of existing Forest Service water management practices, this paper sets forth an alternative strategy. It is a strategy designed to prevent water resource damage on undisturbed, fragile lands, restore already degraded rivers and streams, and ensure that the environmental risks of road construction and logging on the national forests are at least economically justified. This comprehensive antidegradation program can be implemented through the existing authority of the Environmental Protection Agency, state pollution control agencies, and national forest management plans now being issued by the Forest Service. The authors of the paper are Michael Anderson and Craig Gehrke, who are forest planning specialists for the Wilderness Society in Washington, D.C. and Boise, Idaho, respectively. The following consultants made significant contributions to this project. Maggie Coon on water quality criteria, Edward Javorka on economic trade-offs, Dr. Robert Coats on cumulative effects, Dr. Robert Curry on best management practices, and Brian Collins on sediment models. Patricia Harris and Patricia O. Attkisson were responsible for the actual production of this report. This paper, part of our series on important national forest issues, was made possible through generous grants from the Andrew W. Mellon Foundation, and the J.N. Pew, Jr. Charitable Trust.

8. Arkansas Forestry Commission. Best Management Practices Guidelines for Silviculture. : Arkansas Forestry Commission; unk. 21p.

9. Aubertin, G. M.; Patric, J. H. Water Quality After Clearcutting a Small Watershed in West Virginia. Journal of Environmental Quality. 1974; 3(3): 243-249.

A 34-ha (85-acre) gaged watershed on the Fernow Experimental Forest, Parsons, West Virginia, was conventionally clearcut in 1969. Streamflow increased 20 cm (8 inches) during the first year after cutting, but rapid and luxuriant revegetation reduced the flow increase to only 6.4 cm (2.5 inches) during the second year. Water quality remained high. Clearcutting had a negligible effect on the stream's temperature, pH, nonstorm turbidity, and concentrations of dissolved solids, Ca, Mg, Na, K, Fe, Cu, Zn, Mn, and NH4+-N. Storm-period turbidity, nitrate-nitrogen, and phosphate concentrations showed slight increases, while the sulfate concentration decreased. Maximum nitrate-nitrogen concentration of 1.42 ppm was recorded during a 6.4 cm (2.5 inch) rainfall. Success in avoiding damage to water quality was attributed to careful road management, retention of a forest strip along the stream, and rapid, lush vegetative regrowth after clearcutting.

10. Aubertin, G. M.; Smith, D. W.; Patric, J. H. Quantity and Quality of Streamflow After Urea Fertilization on a Forested Watershed: First Year Results. In: Forest Fertilization Symposium Proceedings. : USDA Forest Service; 1973; General Technical Report NE-3: 88-100.

Stream flow was analyzed to determine the effects on the quantity and quality of water flowing from a 74-acre calibrated watershed that had been fertilized with 500 pounds of urea per acre. During the first year after fertilization, no change was detected in the quantity of streamflow. Water quality, as determined from analysis of 829 samples, remained high. Comparison of nitrogen discharge data for the year before and after fertilization revealed approximately 18 percent greater nitrogen discharge after fertilization. Loss of nitrogen was accompanied by increased loss of certain metallic cations.

11. Aumen, N. G.; Grizzard, T. J.; Hawkins, R. H. Water Quality Monitoring in the Bull Run Watershed, Oregon. ; 1989; Task Force Final Report to City of Portland, Oregon, Bureau of Water Works. 108p.

The Bull Run Watershed suppies the Portland, Oregon area with high quality water that is currently untreated except for chloramination. The basin is required to be managed in accordance with Public Law 95-200 by the U.S. Forest Service in cooperation with the City of Portland. This law identifies maintenance of high water quality as the primary management goal, and mandates the establishment of Water Quality Standards and a Water Quality Monitoring Plan to determine compliance with the standards. The management, policies, and activities have been the source of substantial public concern and debate, especially over the past two decades.

12. Bacon, E. J. The Effects of Forest Harvest on Water Quality and Aquatic Life (Phase 1). : University of Arkansas; 1983; Project A-052-ARK. 65p.

13. Bauer, S. B. Evaluation of Nonpoint Source Impacts on Water Quality from Forest Practices in Idaho: Relation to Water Quality Standards. In: Perspectives on Nonpoint Source Pollution, Proceedings of a National Conference; 1985 May 19; Kansas City, MO.: Environmental Protection Agency; 1985: 455-458.

An interdisciplinary task force was appointed by the Board of Health and Welfare to determine the impacts of forest operations on protected uses and make recommendations on water quality standards. Twenty-five forest operations were inspected by the Task Force in 1984 for compliance with the Idaho Forest Practices Act (FPA) and their potential for impacting salmonid fish habitat. Seven of the 25 operations were considered a major impact or hazard to salmonid habitat due to direct delivery of sediment associated with roads or skid trails. At the remaining sites impacts on protected uses were prevented either by site conditions - low geologic hazard, streams with no protected uses - or by good practices. U.S. Forest Service timber sales met or exceeded the Forest Practices Act. Noncompliance on State and private lands was associated primarily with reuse of existing roads near stream channels, failure to identify and use appropriate logging systems in hazardous geologic conditions, and lack of timely installation of erosion control measures.

14. Bauer, S.; Almas, D.; Johnson, M.; Stender, P.; Martin, D. State of Idaho Forest Practices Water Quality Management Plan. Boise, ID: Idaho Department of Health and Welfare, Bureau of Water Quality; 1988.

INTRO: The forest industry in Idaho is an important segment of the state economy which provides employment opportunities, material for construction and wood products. Likewise the land and water associated with forests represent an important part of the state's economy, and is a resource base which must be properly managed to insure their continued value and uses. The most critical concern is protection of fisheries and domestic water supplies which are dependent upon the high quality streams in the forested watersheds of Idaho. The Clean Water Act requires the state to develop a reasonable and effective program to control water pollution associated with nonpoint source activities. This plan is one of several plans which are prepared by the Division of Environment to meet the requirements of the Act. Best management practices (BMPs) are the primary control mechanisms for nonpoint sources of pollution. This concept is the basis for the "feedback loop" recently (Feb. 1987) incorporated into the state Water Quality Standards. The feedback loop refers to the use of momitoring to determine if BMPs are effective in protecting beneficial uses of water. Changes are made to the BMPs when monitoring shows that beneficial uses such as fisheries or domestic water supplies have not been protected. The purpose of this plan is to provide the mechanism by which the feedback loop will be implemented for forest practice activities. The plan identifies the agencies, regulations, and programs for forest practices which are needed to protect streams and lakes for beneficial uses. Goals and objectives are defined for each program area. The plan identifies the existing program, the responsible agency, any needed changes, and the projected resources needed to meet the program objectives. This plan specifies the responsibilities and authorities of the Designated Management Agencies for state, private, and federal lands. Methods for evaluating the program have also been identified.

15. Bauer, Stephen B. Evaluation of nonpoint source impacts on water quality from forest practices in Idaho: Relation to water quality standards. In: Perspectives on nonpoint source pollution: Proceedings of a national conference; 1985 May 19-22; Kansas City, Missouri. : U.S. Environmental Protection Agency; 1985: 455-458.

16. Bauer, Stephen B. [and others], chairman (Idaho Department of Health and Welfare, Division of Environment). Silvicultural nonpoint source task force - Final Report. Boise, Idaho: Idaho Department of Health and Welfare, Division of Environment; 1985 Mar. 42 pages plus appendices.

Task Force Objectives: The Silvicultural Nonpoint Source Task Force was initiated by the Health and Welfare Board in January, 1983 to answer the following questions in regards to the application of Water Quality Standards to forest practices: 1) Do Best Management Practices provide adequate protection for protected uses defined in the Water Quality Standards? 2) Are current forest practices impairing water quality (protected uses) and to what extent? 3) Are the existing regulatory controls for silvicultural operations adequate to prevent water quality impacts?

17. Bauer, Stephen B.; Burton, Timothy A. (Pocket Water, Boise, Idaho; Boise National Forest, Boise, Idaho). DRAFT - Monitoring Protocols to Evaluate Water Quality Effect sof Grazing Management on Western Rangeland Streams. Moscow, Idaho: Idaho Water Resources Research Institute; 1993. 166 pages; Appendixes A-D.

This document describes a monitoring system to assess grazing impacts on water quality in streams of the Western United States. The protocols were developed to assess water quality improvement resulting from stream restoration projects funding under the Clean Water Act (CWA) of 1987 and the Coastal Zone Management Act (CZMA), as amended in 1990. The monitoring methods were selected for application by natural resource professionals typically involved in these projects. This includes resource professionals with backgrounds in soils, range, hydrology, fisheries biology, and water quality. Projects are often implemented by state water quality agencies, Soil Conservation Districts, Soil Conservation Service, U.S. Forest Service, Bureau of Land Management, tribes and other state and federal entities. A goal for this project is to describe methods that are easy to use and cost-effective. This objective is achieved by using methods that reduce sample frequency, minimize the need for specialized equipment, and reduce costly laboratory analyses. The document focuses primarily on attributes of the stream channel, stream bank, and streamside vegetation which are impacted by grazing and are important to support aquatic life. These characteristics are sampled during the low flow conditions in the summer when streams can be waded. The methods require relatively inexpensive equipment compared to standard water chemistry analysis techniques. Implementation of these methods requires an interdisciplinary monitoring team which requires team building and training.

18. Beasley, R. S. Potential effects of forest management practices on stormflow sources and water quality. In: Proceedings, Mississippi Water Resources Conference; 1976. : Water Resources Institute, Mississippi State University; 1976: 111-117.

19. Beasley, R. S.; Granillo, A. B. Sediment Losses From Forest Practices in the Gulf Coastal Plain of Arkansas. In: Jones, E. P. Second Southern Silvicultural Research Conference.; 1982 Nov 4; Atlanta, GA. Asheville, NC: USDA Forest Service; 1982; General Technical Report SE-24: 461-467.

During the first year after clearcutting and intensive mechanical site preparation, mean annual stormflows and sediment losses were significantly higher than levels measured on watersheds which were selectively harvested or left undisturbed. Results are compared with data reported for other locations in the south, and water quality implications are discussed.

20. Beasley, R. S.; Granillo, A. B.; Zillmer, V. Sediment Losses From Forest Management: Mechanical vs. Chemical Site Preparation After Clearcutting. Journal of Environmental Quality. 1986; 15(4): 413-416.

The comparative effects of mechanical and chemical site preparation on water yields and sediment losses following forest clearcutting were evaluated over a 4-yr period in the Athens Plateau area of southwestern Arkansas. After 1 yr of pretreatment measurements, three forested watersheds were clearcut and the residual vegetation and debris were sheared and windrowed but not burned. Three watersheds were clearcut in a similar manner, but received chemical site preparation. Residual trees on two watersheds were injected with 2-4,D amine; the third watershed was aerially sprayed with a mixture of Tordon (active ingredient; picloram [4-amino-3,5,6-trichloropicoline acid) and Garlon (active ingredient; triclopyr [3,5,6-trichloro-2-pyridinyloxyacetic acid]). Three additional watersheds were left undisturbed for controls. Mean annual sediment losses on the mechanically, site prepared watersheds during the first posttreatment year were significantly higher than those from either the chemically site prepared watersheds or controls. Chemical site preparation did not significantly increase sediment losses. Although second yr losses for the mechanical site preparation and control treatments doubled over first yr levels, no significant treatment effect was detected for either site preparation treatment. Third yr losses decreased below first yr losses for all treatments but not to pretreatment year levels. The relatively sharp declines in sediment losses during the third posttreatment year were attributed to rapid regrowth of natural vegetation on the sites.

21. Belt, G. H.; O'Laughlin, J.; Merril, T. Design of Forest Riparian Buffer Strips for the Protection of Water Quality: Analysis of Scientific Literature. : University of Idaho; 1992; Idaho Forest, Wildlife and Range Policy Analysis Group Report No. 8. 35p.

The primary purpose of this report is to identify, evaluate, and sythesize research-based information relating riparian buffer strips to forest practices, water quality, and fish habitat. (Definitions of technical terms such as buffer strip, riparian, forest practices, and water quality are provided in a Glossary at the end of this report.) Scientific literature documenting the role and importance of buffer strips in reducing the impacts of forest practices is extensive. More than 300 scientific papers were located and reviewed; nearly 100 papers and documents were found to be relevant and are cited in this report. Information was extensive on some topics and surprisingly limited on others. A substantial amount of information was found regarding stream temperature changes resulting from the removal of riparian vegetation. Much recent research has focused on the importance of large organic debris (LOD) and how it can be affected by timber harvest. In contrast, little information was found on slash burning and sediment production within buffer strips. Research on some topics was in a case study format, making generalization difficult. Objectives for this report are stated as five focus questions: (1) What is a buffer strip? (2) How do forest practices within buffer strips affect water quality and fish habitat? (3) How effective are buffer strips in reducing impacts of forest practices? (4) What are the issues in buffer strip design? (5) What models are available for use in buffer strip design?

22. Bilby, Robert E. (Weyerhaeuser Co.) Influence of Stream Size on the Function and Characteristics of Large Organic Debris. in: Industry, State and Federal Programs Designed to Assess and Protect Water Quality Associated with Managed Western Forests. New York, NY: NCASI; 1985 Jul; NCASI TB-466. 1-60.

For the past seven years, the Southern and West Coast Regional Meetings have featured one or more sessions covering research and field investigations on the impact of forestry management practices on receiving water quality and utility. This technical bulletin is an assembly of eight presentations on programs designed to develop or implement forest management practices that protect water quality and stream aquatic habitat. Programs include federal studies and method development work being conducted by the USDA Forest Service. State program elements discussed include reviews of Forest Practice Act effectiveness. Industry activities presented include programs to develop and implement Best Management Practices for Western States. All were presented at the West Coast Regional Meeting in 1985. The session at which these papers were presented was arranged by Dr. George G. Ice, Research Forester located at the West Coast Regional Center. In the first paper, Dr. Robert Bilby, Weyerhaeuser Company, reviews research on the role of large organic debris in streams and important considerations in managing woody debris. Investigations by Weyerhaeuser Company have shown that, size of debris influences its stability and channel-modifying role for larger streams but that size has apparently less significance for smaller streams. In the second paper Dr. William Lawrence, the Weyerhaeuser Company and Dr. George Ice review the development of a forest managers guide to stream habitat protection. The technical staff of several forest-industry companies have developed this managers guide which focuses on protecting salmonid stream habitat. Specific chapters in this report will cover, (a) fish biology, (b) stream productivity, (c) organic debris, (d) forest hydrology, (e) forest management, (f) streamside management zones, and (g) state Forest Practice Acts. In the third paper, Dr. George Ice summarizes the methods available to member companies of NCASI to access technical information on forest management practices and water quality. An index to NCASI Technical Bulletins and Special Reports Related to forest management and receiving water quality protection accompanies this presentation. The next three presentations cover federal activities related to landslides in forestlands and methods of assessing risk and impacts. The first, by Dr. Raymond Rice, U.S. Forest Services, reviews the use of discriminant functions to identify sites with high or low risk of landsliding. Two examples of discriminant function application for forest sites in California are provided. In the second paper, Dr. Frederick J. Swanson, Duane Dipert, and Chris Roach of the U.S. Forest Service discuss studies in the Siuslaw National Forest to assess the effectiveness of leave areas. This study is designed to determine (a) consistency of leave area prescription, and (b) performance of leave areas in mitigating in-unit slide frequency. Actual leave-area implementation has been about 97 percent successful compared to an estimate of 73 percent successful prior to this study. In the third paper, George Bush of the U.S. Forest Service reviews the development of procedure by the Siuslaw National Forest to assess the cumulative effects of forest management activities. The procedure involves separation of land-units into assessment areas, and comparison of harvesting rates (for all ownerships) against a harvesting rate considered to be a threshold-of-concern. The final two papers deal with state Forest Practice Act Programs in Idaho and California. Dale McGreer, Potlatch Corporation, discusses the recent task group assessment of the effectiveness of the Idaho Forest Practices Act (IFPA). With rule modifications (most already being considered) the IFPA can protect water quality. Management practices were found lacking on small, non-industrial tracts and on State of Idaho Department of Land sites. The key to making the IFPA work was judged to be adequate administration and enforcement of the rules. The final paper by Arne S. Skaugset, Simpson Timber Company, considers the history of Forest Practice Rules in California and the impending assessment of the effectiveness of the silvicultural nonpoint source control program. Conditional approval of the CFPA by the state will be reevaluated in 4 years after an assessment where protocol is still to be determined.

23. Bisson, P. A. Annual Fertilization and Water Quality - Final Report. Centralia, WA: Weyerhaeuser Company; 1982; Technical Report 050-5411-02. 32p.

The project was undertaken to evaluate the potential effect of annual forest fertilization on stream water quality. This report summarizes the findings to date, from initiation of the study in July 1980 to termination of sampling in October 1981. No water quality standards were violated in any of the experimentally fertilized watersheds. Fertilizer nitrogen loss estimates varied from 1.9 to 9.0 percent of the total nitrogen applied. High fertilizer export from one watershed was apparently related to that watershed's extensive fertilization history, thus suggesting, but not confirming, that repeated applications may lead to progressively greater losses. High nitrogen export from another watershed appeared to be caused by unusally heavy urea application to the stream and to accelerated runoff during snowmelt.

24. Bisson, P. A. Final Report: 1988 Weyerhaeuser Forest Fertilization Water Quality Monitoring Studies: Forks Creek, Ryderwood, Silver Lake. Weyerhaeuser Company Technology Center, Tacoma, WA: Weyerhaeuser Company; 1988. 26p.

Water quality monitoring of Weyerhaeuser's forest fertilization projects in 1988 took place at three separate locations: Forks Creek, Ryderwood, and Silver Lake. The goal of each study was to determine if drinking water standards or aquatic toxicity thresholds for dissolved nitrogen were exceeded during or following fertilizer application. Critical water thresholds for nitrate + nitrite-N, total ammonia-N, and Kjeldahl-N (organic nitrogen) were taken to be 10.0 mg/1, 1.8 mg/1, and 1,000 mg/1, respectively. All fertilizer applications followed pre-1988 Forest Practice guidelines, i.e., 50 ft. buffer strips along type 3 waters, and no buffer strips along Type 4 or Type 5 waters. In each instance, aerial application of urea prill resulted in elevated dissolved nitrogen concentrations in the study streams. Peak Kjeldahl-N concentrations were always less than 4.0 mg/1 and were more commonly less than 2.0 mg/1. Peak post-fertilization nitrate-N concentrations were always less than 2.0 mg/1 and usually less than 1.0 mg/1. Maximum post-fertilization total ammonia-N concentrations were always less than 0.5 mg/1 and usually less than 0.3 mg/1. Based on prevailing pH and temperature, the estimated maximum un-ionized ammonia-N concentration at the majority of monitoring stations in 1988 was 0.0003 mg/1. Post-fertiliization averages for nitrate-N and total ammonia-N were approximately half of the measured peak concentrations. In no cases were drinking water standards or estimated aquatic toxicity thresholds exceeded at any of the study sites.

25. Bisson, P. A.; Ice, G. G.; Perrin, C. J.; Bilby, R. E. Effects of Forest Fertilization on Water Quality and Aquatic Resources in The Douglas-Fir Region. In: Proceedings of the 1991 Forest Fertilization Conference. University of Washington, Seattle, WA; In Press.

Increased concentrations of three species of dissolved nitrogen occur in surface waters after urea application: (1) urea-N (often reported as Kjeldahl-N or organic-N), which is present for only a few days, (2) ammonia-N, which is often elevated for several weeks to several months, and (3) nitrate-N, which may be elevated for up to a year or more. Peak urea-N levels immediately after fertilization usually range from 0.1 mg/L to 50 mg/L depending on the percent of watershed fertilized, drainage density, urea application rate, precipitation, and the length and width of buffer strips (unfertilized areas) along riparian corridors. Peak concentrations of total ammonia-N (ionized and un-ionized ammonia) after fertilization are typically 0.1 mg/L to 0.5 mg/L depending on the factors given above, as well as temperature and soil chemistry. Relatively high concentrations of ammonia have been associated with fertilization at low temperatures, which inhibit nitrification. The highest nitrate-N concentrations reported from Pacific Northwest streams after fertilization have exceeded 3.0 mg/L, but peak concentrations ranging from 0.1 mg/L to 1.0 mg/L are more typical of the Douglass Fir region. Estimated percentages of fertilizer nitrogen exported from watersheds in streams during the first year range from less than 1% to more than 10% of the total nitrogen applied. Baseline nitrate levels may be increased in watersheds with histories of multiple fertilization. During normal operations neither drinking water standards (10.0 mg/L nitrate=N, 0.5 mg/L ammonia-N) nor aquatic toxicity thresholds (approximately 1.2 mg/L total ammonia-N) are exceeded. However, increased nitrogen in streams has the potential to promote the growth of periphyton. In some streams increased primary production can lead to enhanced production of aquatic invertebrates and fishes, although enhanced fish production after forest fertilization has not yet been clearly demonstrated in the Pacific Northwest. Transport of fertilizer derived nitrogen downstream to hydraulic sinks in the drainage system (lakes, wetlands) may contribute to accelerated eutrophication if these waterbodies are nitrogen-limited. Taken together, however, the majority of evidence suggests that forest fertilization in the Douglass Fir region does not cause exceedance of water quality standards. Although increases in dissolved nitrogen relative to baseline levels may be considerable, adverse effects on beneficial uses have not been shown. Therefore, we conclude that while forest fertilization may cause changes in the nitrogen dynamics of receiving waters it does not result in water quality impairment, provided reasonable precautions are taken to minimize direct entry of urea to streams from aerial applications and to prevent surface runoff from urea storage and loading areas.

26. Bisson, Peter A.; Quinn, Thomas P.; Reeves, Gordon H.; Gregory, Stan V. Best Management Practices, Cumulative Effects, and Long-Term Trends in Fish Abundance in Pacific Northwest River Systems. Springer-Verlag-Watershed Management. 1992 Feb 12; EB15 42844$$$$7: 189-232.

Although it is widely believed that forest management has degraded streams and rivers, quantitative relationships between long-term trends in fish abundance and forestry operations have not been successfully defined. In this article we review the difficulties in describing cumulative effects of forest management on fishes of the Pacific Northwest. Despite uncertainties in interpreting long-term trends from catch and escapement statistics as well as widespread programs of hatchery production, many local fish populations are declining. We suggest that trends in the abundance of individual populations are often of limited use in identifying the cumulative effects of forest management within a river system. Shifts in the composition and organization of fish communities may provide more comprehensive evidence of the extent of environmental alteration. Reduced stream habitat complexity has been one of the most pervasive cumulative effects of past forest practices and probably has contributed to significant changes in fish communities, particularly when accompanied by other land use activities that have led to straightened, confined channels. In simplified streams a few fish species have characteristically been favored while others have declined or disappeared completely. Likewise, fish culture practices have resulted in overall losses of genetic diversity among species. In order to protect channel complexity and biodiversity, best management practices (BMPs) should include measures to preserve physical and biological linkages between streams, riparian zones, and upland areas. Connections must include transfer processes that deliver woody debris, coarse sediment, and organic matter to streams, as these materials are largely responsible for creating and maintaining channel complexity and trophic diversity. Past forest practice regulations have required attainment of individual water quality standards, such as temperature or dissolved oxygen, and have been aimed at protecting certain life history stages of single species (e.g., salmon eggs in spawning gravels). This approach is inadequate to achieve the goal of restoring and maintaining natural levels of complexity at the level of a stream ecosystem. New BMPs are beginning to address this issue by prescribing riparian management zones with a greater range of vegetative species and structural diversity, thus providing for future sources of large woody debris, floodplain connections, and other linkages important to ecosystem function. Benefits of new BMPs in terms of improved habitat complexity and increased diversity of fishes on the scale of a river basin will require coordinated planning and extensive application, and will take years - perhaps decades - to become apparent.

27. Blackburn, W. H.; DeHaven, M. G.; Knight, R. W. Forest Site Preparation and Water Quality in Texas. In: Kruse, E. G.; Burdick, C. R.; Yousef, Y. A. Proceedings for Environmentally Sound Water and Soil Management.; 1982 Jul 20; Orlando, FL. New York: American Society of Civil Engineers; 1982: 57-66.

Nine small watersheds were instrumented in east Texas to determine the effect of site preparation practices applied in 1980 on water quality and yield. Following treatment, during the first eight months of 1981, stormflow volumes increased with the intensity of the site disturbance. Watersheds sheared and windrowed produced the greatest amount of stormflow (7.77 cm), followed by roller chopping (4.04 cm) and the undisturbed watersheds (0.78 cm). The shearing and windrowing treatment exposed 59% of the mineral soil as compared to 16% on the chopped watersheds. Sediment losses were significantly greater from the sheared (2201 kg/ha) than from the chopped (13 kg/ha) or undisturbed watersheds(3 kg/ha). Total nitrogen losses were nearly 20 times greater from sheared (2.14 kg/ha) than from undisturbed (0.12 kg/ha) watersheds, and three times greater than from chopped watersheds (0.76 kg/ha). Total phosphorus loss during 1981 was only 0.20 kg/ha from sheared watersheds, but was significantly greater than from chopped or undisturbed watersheds. Potassium, magnesium, and sodium export was highest on the sheared watersheds; however, calcium export was greater from the chopped watersheds.

28. Blackburn, W. H.; Wood, J.; DeHaven, M. G. Forest Harvesting and Site Preparation Impacts on Stormflow and Water Quality in East Texas. In: Forestry and Water Quality: A Mid-South Symposium.; Little Rock, Arkansas. ; 1985: 74-93.

Nine small (6.4 to 6.8 ac) forested watersheds in East Texas were instrumented in 1979 to determine the effect of harvesting and mechanical site preparation on stormflow and water quality. Three replications of three treatments were used: 1) clearcutting, followed by shearing, windrowing and burning, 2) clearcutting, followed by roller chopping and burning, and 3) undisturbed control. Following site preparation 58% of the surface soil was exposed on the sheared watersheds compared to 15% on the chopped watersheds. The first year after site preparation, sheared watersheds yielded the greatest amount of stormflow (5.8 inch), followed by chopped (3.3 inch) and undisturbed (1.0 inch) watersheds. Stormflow was less than one-half those amounts during the second, third, and fourth post-treatment years. First year sediment, nitrate, ortho-phosphate, and total phosphorus losses were significantly greater from sheared than from chopped or undisturbed watersheds. Total nitrogen loss the first year following treatment was significantly greater from sheared and chopped watersheds than from undisturbed watersheds. Sediment and nutrient losses from both the sheared and chopped watersheds the second, third, and fourth years following treatment were greatly reduced and were approaching losses from undisturbed watersheds. Losses reported in this study, although significantly different between treatments, are small and well below tolerable levels. Treatment differences are attributed primarily to the degree of surface disturbance and the amount of mineral soil exposed. Sediment and nutrient losses can be minimized by limiting shearing and windrowing activities to the more gentle slopes. Roller chopping on the other hand, caused a moderate increase in water yield and had a minimal impact on sediment and nutrient losses from watersheds with slopes up to 25%.

29. Borg, H.; Hordacre, A.; Batini, F. Effects of logging in stream and river buffers on watercourses and water quality in the southern forest of Western Australia. Australian Forestry. 1988; 51(2): 98-105.

During the summers of 1984/85 and 1985/86 several stream and river buffers were logged in the southern forest of Western Australia to assess the effects on the watercourses and water quality. All cutting areas were regenerated to forest soon after logging. Reducing the width of river buffers from the usual 200 m to 100 m (3 trials), and reducing the width of stream buffers from the usual 100 m to 50 m (2 trials), had no effect on the watercourses or water quality. The complete removal of stream buffers (1 trial) introduced logging debris to the stream channel and led to minor changes in the stream channel profile and algal blooms. However, it had no detectable effect on suspended sediment concentrations in the stream. In all 6 trials some minor erosion occurred on the boundary tracks. In 2 trials, major logging roads crossed a stream. At these crossings, organic matter and road surfacing material were found in the watercourses. From these 6 trials it was concluded that stream and river buffers in the southern forest of Western Australia can be reduced to half their usual width without any detrimental effects on the watercourses as long as logging is confined to the dry season, and all roads and tracks are built and drained properly and located away from the watercourses. Owing to the risk of damage to a watercourse, the complete removal of buffers should not be made a general practice.

30. Borg, H.; Stoneman, G. L.; Ward, C. G. The effect of logging and regeneration on groundwater, streamflow and stream salinity in the southern forest of Western Australia. Journal of Hydrology, Netherlands. 1988; 99(3/4).

Four small catchments (Crowea, Poole, Iffley and Mooralup) were selected in 1975 to study the effect of heavy selection cutting and clear-felling followed by regeneration on streamflow, stream salinity and groundwater levels. The catchments were logged between November 1976 and March 1978. Regeneration began within eighteen months after the completion of logging. During 1976-85 the annual rainfall in the region was generally below the long-term mean. This probably influenced the magnitude and duration of the hydrologic response to logging and regeneration, but not the general trends. Groundwater levels rose for two to four years after logging and then started to fall again. They can be expected to reach the values they would have been without logging within fifteen years from the beginning of regeneration. In the relatively dry Mooralup catchment, logging had little effect on the groundwater level. As a result of logging streamflow increased for 1977 and 1978 then gradually declined again as the vegetation regenerated. Streamflow is also likely to be back to pre-logging values within fifteen years from the beginning of regeneration. In the Mooralup catchment, where streamflow volumes are naturally small, this may have happened after six years of regeneration. Flow-weighted mean annual stream salinities rose for one to three years after logging but have declined since. Even at their highest level they remained below the upper limit for high-quality drinking water. Stream salinities are likely to return to the level they would be at without logging at the same time as streamflow and groundwater levels.

31. Boschung, H.; O'Neil, P. The Effects of Forest Clearcutting on Fishes and Macroinvertebrates in an Alabama Stream. In: Warmwater Streams Symposium. : American Fisheries Society; 1981: 200-217.

INTRO: This study attempts to determine if clearcutting, as practiced in the southern Appalchians, affects the fishes and macroinvertebrates in a forest stream. Previous studies have dealt with the effects of deforestation or clearcutting on water quality, including sedimentation, particulate matter, temperature, runoff, and streamflow. A review of the voluminous literature on the effects of forest management on the ecosystem is beyond the scope of this paper; however, none, to our knowledge, relates to the effects of clearcutting on warmwater fishes of the southern Appalachians.

32. Boschung, H.; O'Neil, P. The Methods and Results of a Study to Determine the Effects of Clearcutting on the Macroinvertebrates and Fishes of a Southern Appalachian Forest. In: Research and Field Investigations on the Impact of Southern Forestry Management Practices on Receiving Water Quality and Utility. : NCASI; 1980; Technical Bulletin No. 337: 28-51.

Introduction: Numerous papers have addressed the subject of the effects of clearcutting and its associated disturbances (road building, skid trails, etc.) on forest fauna. A review of the voluminous literature is beyond the scope of this paper; suffice it to say, none of the literature relates to the effects of forest clearcutting on warmwater fishes of the southern Appalachians. The main thrust of the research reported herein involved the periodic sampling of fishes and macroinvertebrates in experimental and control streams before and after clearcutting and then making data comparisons using various measures of diversity. As part of the experimental design, two adjacent streams having similar characteristics were selected for the study. The streams, Cheaha Creek (experimental stream) and Barbaree Creek (control stream), are typical mountain streams inh the Talladega National Forest, Clay County, Alabama.

33. Bouchard, D. C.; Lavy, T. L.; Lawson, E. R. Mobility and Persistence of Hexazinone in a Forested Watershed. Journal of Environmental Quality. 1985; 14(2): 229-233.

The concentration of hexazinone in soil, water, and plant tissue was monitored following hexazinone application (2.0 kg ai/ha) to an 11.5-ha watershed in northwestern Arkansas. The hexazinone concentration in the top 10 cm of soil on the watershed decreased to approximately 10% of the initial concentration in 42 days. Hexazinone dissipation rate on the watershed was more rapid than could be accounted for soley by degradation. Leaching of hexazinone to lower soil depths probably was important to hexazinone dissipation. Hexazinone degradation in soil incubated at 10 and 30 C followed first-order kinetics and had a half-life of 77 days at 30 C. Hexazinone was stable in incubated stream water requiring several years for 50% disappearance of the compound at 30 C. The maximum hexazinone concentration in the stream that drained the watershed was 14 ug/l, and hexazinone residues (<3 ug/l) were detected in stream discharge over 1 yr after application. The amount of hexazinone transported from the watershed in stream discharge represented 2.0 to 3.0% of the amount of initially applied. Analyses of oak foliage and leaf litter collected from the forest floor indicated that <0.10% of the hexazinone applied was returned to the forest floor in leaf deposition.

34. Brown, George W. (Forest Hydrologist, School of Forestry, Oregon State University). The Impact of Timber Harvest on Soil and Water Resources. Corvallis, Oregon: Oregon State University Extension Service; 1973; Extension Bulletin 827.

Oregon's forests appear as a highly diverse set of complex ecosystems in which soil, climate, topography, and the trees themselves interact to create the forests we see. Man and his timber harvest activities add to this diversity and complexity. Generalizations about the impact of timber harvest are difficult to make without specifying the characteristics of the natural system and the forest practice. Clearcutting as a forest practice, for example, is neither uniformly good or bad for soil and water resources, but must be evaluated site by site. Soil is the most basic forest resource. It provides the medium for plant growth and is a reservoir for water. Surface erosion is the result of exposing mineral soil to rain or severely disturbing or compacting surface soil. Infiltration rates must be reduced substantially to induce surface runoff. Forest fires or severe slashburning, poorly drained or constructed roads, and ground skidding on wet soils may produce such conditions. The hi-lead method of yarding, most common to the Northwest, does not increase substantially the amount of surface erosion. Mass soil movement is a catastrophic form of natural erosion and can be produced by road construction in unstable, steep topography. Poor road location, design and construction may trigger large landslides that damage streams and structures. This is the most important erosion process in western Oregon, yet we know very little about the processes, how to predict their occurrence, or how to control them. Timber harvest operations can affect both streamflow and water quality. Trees use great quantities of water for transpiration. When a forest is harvested, water normally transpired is available for streamflow. Large increases in the annual flow and summer flows have been observed after clearcutting. Normal timber harvest operations may increase peak flows from small fall and spring storms, but not the large mid-winter events. This is because soils are saturated in both forested and non-forested areas by mid-winter. In either case, any additional precipitation that falls is readily available for stream flow. Sediment temperature, and dissolved oxygen are water quality characteristics that may be affected by timber harvest, again depending upon the type of forest system and the way in which the harvest operation is conducted. Controlling sediment requires controlling the erosion from surface soils or mass soil movement. Controlling temperature changes may be accomplished by leaving shade along streams. Maintaining acceptable levels of dissolved oxygen in streams is keyed to minimizing temperature changes and debris accumulation in the channel. Controlling impacts of timber harvest on soil and water resources is a difficult task, one that requires a high degree of skill. The forester must understand not only the natural system he manages, but how his activities interact with this system. Diversity usually precludes easy solutions. The solution to these complex problems rests with land managers and the skill, time and money they are able to apply.

35. BROWNLEE, M. J.; SHEPHERD, B. G.; BUSTARD, D. R. SOME EFFECTS OF FOREST HARVESTING ON WATER QUALITY IN THE SLIM CREEK WATERSHED IN THE CENTRAL INTERIOR OF BRITISH COLUMBIA CANADA. Canadian Technical Report of Fisheries and Aquatic Sciences. 1988: 1-41.

The effects of forest harvesting practices on water quality were examined within a watershed 80 km east of Prince George in the central interior of British Columbia between 1971 and 1975. Suspended sediment loading in the study stream, Centennial Creek, increased 4 to 12 times over corresponding levels in an adjacent control stream. Mainline road development was the main source of increased levels of sediment which persisted for the duration of the three years of study. At associated tributaries, erosion from skid trails, landings, road crossings and streambank damage occurred during and after logging, but in contrast, it did not persist beyond the first summer after logging. Mean water temperatures increased 1 to 3 C following logging to the edge of small tributary streams. Diurnal fluctuations more than doubled. Although maximum water temperatures in these small streams increased up to 9 C they remained within tolerance levels for salmonids. When instream nutrients were at high levels, logged areas had 1-2 times the orthophosphate concentrations, 2-3 times the total phosphate concentrations, and up to 5 times the nitrate concentrations present in the unlogged watershed. The implications of this study's results to forest harvesting operations in the interior of British Columbia are discussed.

36. Burton, T. A. Monitoring Stream Substrate Stability, Pool Volumes, and Habitat Diversity. Boise, ID: Idaho Department of Health and Welfare, Division of Environmental Quality; 1991; Water Quality Monitoring Protocols - Report No. 3.

INTRO: On a regional scale in Idaho, there are basically two major stream types that are clearly differentiated on factors limiting fish abundance: Stream/riparian systems dominated by forest overstory, and those dominated by grass/shrub riparian vegetation. Forest canopy dominated streams occur primarily in mountain settings in Idaho and occur generally on gradients greater than 1.5 percent, while grass/shrub streams occur in intermontane valleys, mountain meadows, and plains and are graded generally less than 1.5 percent. As indicated by Kozel and Hubert (1989b), Moore and Gregory (1989), and Klamt (1976), salmonid production in forested mountain streams is limited primarily by habitat structure. Such streams generally occur on gradients greater than 1.5 percent. Physical habitat diversity seems to be the key to fish production because in steeper gradient streams, resting areas and refugia are physically limited. Fish abundance is often related to overhead bank cover, the number and complexity of pools, backwater eddies, runs and glides, amount of large woody debris, and sediment accumulation. In some cases, canopy closure is limiting primary production and availability of drifting prey due to lack of light energy penetration in these forest streams. At the pre-emergent stage, sediment accumulations affect embryo survival, because the deposits coincide with low-energy sites used by spawning fish. At rearing stages, sediment accumulations also affect habitat quality in low-energy sites such as pools. Pool filling and destabilization as a result of sedimentation of the substrate can alter habitat structure and diversity important to fish. The subject of fine sediment effects on salmonids is summarized for the Northern Rocky Mountains in Idaho by Chapman and McLeod (1987). Protocols for the effects of sediment on habitat are contained in: Water Quality Monitoring Protocols Report numbers 1 and 2 (IDHW, DEQ 1990/91) which address sediment impacts to salmonid incubation and intercobble living space. In addition, an excellent method for monitoring habitat structure and diversity and fish abundance is according to the basin-wide technique developed by Hankin and Reeves (1988).

37. Campbell, I. C.; Doeg, T. J. Impact of timber harvesting and production on streams: a review. Australian Journal of Marine and Freshwater Research. 1989; 40(5).

A discussion of the effects of timber harvesting in Australia on streamflow, water quality (increases in sediments, suspended solids and organic material, and their effects on nutrient status, dissolved O2, light availability and temp.) and stream biota, and the effects of pesticides, fire and plantations of exotic species.

Timber harvesting operations have significant effects on both water quantity and water quality. The effects on water quantity have been well documented both in Australia and elsewhere. The effects on water quality are less widely appreciated, and include elevated concentrations of dissolved salts, suspended solids and nutrients, especially during peak flow periods. Several Australian studies have failed to measure peak flow transport of suspended solids, or have measured it inadequately, thus severely underestimating transport. The major short-term effects of timber harvesting on the aquatic biota result from increased sediment input into streams or increased light through damage to, or removal of, the riparian vegetation. Sediment which settles on, or penetrates into, the stream bed is of more concern than suspended sediment, and can lead to long-term deleterious changes to fish and invertebrate populations. Increased light causes an increase in stream primary production which may increase invertebrate densities, and alter community composition. These biological consequences have not yet been adequately investigated in Australia. Longer-term effects, as yet not investigated in Australia, include changes to stream structure as the regrowth forest has fewer large logs to fall into the stream. These large logs play a major role as habitat and retention structures in streams. There has been no attempt to evaluate the effect of timber production activities, including pesticide use and fuel reduction burning, on the Australian stream biota. Likewise, although buffer zones are widely advocated as a protection measure for streams in Australia, there have been no studies to evaluate their effectiveness.

38. CAMPBELL, I. C.; DOEG, T. J. IMPACT OF TIMBER HARVESTING AND PRODUCTION ON STREAMS A REVIEW. Australian Journal of Marine and Freshwater Research. 1989; 40(5): 519-540.

Timber harvesting operations have significant effects on both water quantity and water quality. The effects on water quantity have been well documented both in Australia and elsewhere. The effects on water quality are less widely appreciated, and include elevated concentrations of dissolved salts, suspened solids and nurients, especially during peak flow periods. Several Australian studies have failed to measure peak flow transport of suspended solids, or have measured it inadequately, thus severely underestimating transport. The major short-term effects of timber harvesting on the aquatic biota result from increased sediment input into streams or increased light through damage to, or removal of, the riparian vegetation. Sediment which settles on, or penetrates into, the stream bed is of more concern than suspended sediment, and can lead to long-term deleterious changes to fish and invertebrate populations. Increased light causes an increase in stream primary production which may increase invertebrate densities, and alter community composition. These biological consequences have not yet been adequately investigated in Australia. Longer-term effects, as yet not investigated in Australia, include changes to stream structure as the regrowth forest has fewer large logs to fall into the stream. These large logs play a major role as habitat and retention structures in streams. There has been no attempt to evaluate the effects of timber production activities, including pesticide use and fuel resudction buring on the Australian stream biota. Likewise, although buffer zones are widely advocated as a protection measure for streams in Australia, there have been no studies to evaluate their effectiveness.

39. Chamberlin, T. W. Influence of Forest and Rangeland Management on Anadromous Fish Habitat in Western North America; 3. Timber Harvest. Pacific Northwest Forest and Range Experiment Station: USDA Forest Service; 1982; General Technical Report PNW-136. 33p.

Felling and yarding of trees cause changes to anadromous fish habitat in western North America through changes in water and land-system processes. Harvesting may substantially change the distribution of water and snow on the ground, the amount intercepted or evaporated by foliage, the rate of snowmelt or evaporation from snow, the amount that can be stored in the soil or transpired from the soil by vegetation, and the physical structure of the soil, which governs the rate and pathways of water movement to stream channels. All of these factors may affect streamflow. Forest harvesting activities directly influence fish habitat in four habitat in four major areas: acceleration of erosion and mass-movement processes; introduction and removal of organic debris; alteration of channel shape; and removal of streamside vegetation. With adequate knowledge of the characteristics of particular streams, enhancement of some habitats is possible. Evidence suggests that increased runoff from evapotranspiration and interception losses alone does not increase high flows sufficiently to be of concern. Much greater flow increases may be caused by synchronization of snowmelt or in conjunction with rain-on-snow events. The principal water quality parameters that may be influenced by felling and yarding are temperature, suspended sediment, dissolved oxygen, and nutrients. Other habitat factors which may be influenced by timber harvesting include: streambed material compostion and scour; steambank structures; cover; riparian vegetation; and migration barriers.

40. Clingenpeel, J. A.; Cochran, B. G. Using Physical, Chemical and Biological Indicators to Assess Water Quality on the Ouachita National Forest Utilizing Basin Area Stream Survey (BASS) Methods. Hot Springs, AR: USDA Forest Service.

The Ouachita National Forest (ONF) has developed a series of Best Management Practices (BMP's) designed to protect water quality and associated beneficial uses (fisheries, municipal water supplies, etc.). A monitoring program is necessary to document the effectiveness of that protection. The Basin Area Stream Survey (BASS) methodology provides a monitoring link from BMP's to the aquatic ecosystems. The goal of BASS is to identify the physical, chemical and biological characteristics of a stream in a format that will allow comparisons with other streams, and indicate when a stream is being impacted. Six index streams within three ecoregions were selected and inventoried in 1990, 1991, and 1992, to serve as baseline data sources. The South Fork of Alum Creek and Bread Creek represent the Ouachita Mountain Ecoregion, Caney Creek and Brushy Creek represent the Central Subdivision of the Ouachita Mountain Ecoregion, and Jack Creek and Dry Creek represent the Arkansas River Valley Ecoregion.

41. Coats, Robert N.; Miller, Taylor O. Cumulative silvicultural impacts on watersheds: A hydrologic and regulatory dilemma. Environmental Management. 1981; 5(2): 147-160.

Because of the nature of watersheds, the hydrologic and erosional impacts of logging and related road-building activities may move offsite, affecting areas downslope and downstream from the operation. The degree to which this occurs depends on the interaction of many variables, including soils, bedrock geology, vegetation, the timing and size of storm events, logging technology, and operator performance. In parts of northwestern California, these variables combine to produce significant water quality degradation, with resulting damage to anadromous fish habitat. Examination of recent aerial photographs, combined with a review of public records, shows that many timber harvest operations were concentrated in a single 83 km2 watershed in the lower Klamath River Basin within the past decade. The resulting soil disturbance in this case seems likely to result in cumulative off-site water quality degradation in the lower portion of the Basin. In California, both state and federal laws require consideration of possible cumulative effects of multiple timber harvest operations. In spite of recent reforms that have given the state a larger role in regulating forest practices on private land, each timber harvest plan is still evaluated in isolation from other plans in the same watershed. A process of collaborative state-private watershed planning with increased input of geologic information offers the best long-term approach to the problem of assessing cumulative effects of multiple timber harvest operations. Such a reform could utimately emerge from the ongoing water quality planning process under Section 208 of the amended Federal Water Pollution Control Act.

42. Corbett, E. S.; Lynch, J. A.; Sopper, W. E. Forest Management Practices as Related to Nutrient Leaching and Water Quality. In: Conference on Non-Point Sources of Water Pollution Proceedings.; Virginia Water Resources Research Center. Blacksburg, VA; 1975: 157-173.

43. Corbett, Edward S.; Spencer, Warren. Effects of Management Practices on Water Quality and Quantity: Baltimore, Maryland, Municipal Watersheds. Municipal Watershed Management Symposium Proceedings. : USDA Forest Service, Northeastern Forest Experiment Station, Upper Darby, PA; 1975; General Technical Report NE-13: 25-31.

To complement its water-management program, the City of Baltimore, with the assistance of the Northeastern Forest Experiment Station, is conducting research on the effects of vegetation management on water yield and quality. Three small watersheds, ranging in size from 22 to 38 acres, have been selected for this purpose. Two of the watersheds, formerly in open land except for hardwoods along the riparian zones, were reforested 17 years ago with white and loblolly pines. Converting the open land to a pine forest caused a substantial reduction in water yield. The effects of removing riparian-zone vegetation and also thinning the young pine plantations are evaluated from the viewpoint of the municipal watershed manager.

44. Cowling, Ellis B., Associate Dean for Research (School of Forest Resources, NC State University, Raleigh, NC). International Aspects of Acid Deposition. in: Herrmann, Raymond; Johnson A. Ivan, Water Resources Field Support Lab, NP Service, Colorado State University; Woodward-Clyde Consultants, Englewood, Colorado. Acid Rain - A Water Resources Issue for the 80's - Reprinted from Proceedings of the American Water Resources Association, International Symposium on Hydrometeorology. Bethesda, Maryland: American Water Resources Association (AWRA); 1982 Jun; c1983: 3-12.

In recent decades, "acid rain" has become a dominant feature of man induced change in the chemical climate of the Earth. Wherever fossil fuels are burned, metal ores are smelted, and materials are processed on a large scale, various gaseous, aerosol, and particulate waste products are released into the atmosphere. These substances and their reaction products are dispersed by meteorological processes and deposited on vegetation, soils, and surface waters, often at great distances from the source of emissions. Concern has arisen in many countries about effects on forests, fish, crops, water quality, materials, and human health. The result is a growing concern about international exchange of air pollutants, wet and dry deposition of strong acids and other acidifying substances, as well as the associated deposition and mobilization of toxic metals and the leaching of nutrient substances. These concerns developed originally among the Scandinavian countries, Great Britain and Germany, and other industrial nations of central Europe. More recently they have also developed between Canada and the United States. International cooperation between atmospheric scientists and biologists and among leaders of forestry, agricultural, water resource, industrial, and governmental organizations is resulting in a general concensus about both the phenomena involved and about strategies for the management of acid deposition.

45. Cubbage, Federick W.; Siegel, William C.; Lickwar, Peter M. State Water Quality Laws and Programs to Control Nonpoint Source Pollution from Forest Lands in the South. Water: Laws and Management. 1989 Sep: 8A-29 - 8A-37.

Since enactment of the 1972 Federal Water Pollution Control Act Amendments, substantial federal and state efforts have been initiated to control nonpoint source pollution emanating from forest lands. This paper briefly reviews the background of federal laws enacted to maintain water quality statues and programs that affect forestry in the South. State statutes and programs include general water quality laws that could be construed to apply to forestry practices, specific legislation that addresses silviculture and harvesting, related laws that indirectly affect forested lands, voluntary best management practice programs, and financial incentives. The state programs for controlling nonpoint source pollution are summarized, based on the results of a recent survey of southern forestry and lead environmental agencies.

46. Cubbage, Frederick W. ,. Siegel, William C. The Law Regulating Private Forest Practices. Journal of Forestry. 1985: 538-545.

47. Curry, Robert R. Water quality protection in forest management: are best management practices working? Robert Z. Callaham and Johanna J. Devries, Technical Coordinators. Proceedings of the California Watershed Management Conference; 1986 Nov 18; West Sacramento, California. Berkeley, California: Wildland Resources Center, Division of Agriculture and Natural Resources, University of California; 1987 Feb: p. 55. 7 pages.

The best management practices (BMP) concept is well established and provides a practical approach to maintaining water-quality-related values. Numerous ongoing studies that address effectiveness of BMPs and that together comprise the data base upon which evaluation must be based are not quite ready for release. This paper addresses, therefore, primarily generic problems with current BMPs with specific examples and research-derived data directed at streamzone protection BMPs and fish habitat protection.

48. Davis, E. A.; Ingebo, P. A.; Pase, C. P. Effect of a Watershed Treatment with Picloram on Water Quality. : USDA Forest Service, Rocky Mountain Forest and Range Experiment Station; 1968; Research Note RM-100. 4p.

A watershed treatment of soil-applied picloram pellets for the control of chaparral brush resulted in the movement of detectable amounts of picloram into the stream water. The highest concentration found was 0.37 ppm. After 16 months and 40" of accumulated rainfall, picloram was no longer detectable in the stream water.

49. Dissmeyer, George E.; Foster Bennett. Some Economic Benefits of Protecting Water Quality. Forests, the World, & the Profession: Proceedings fo the 1986 Society of American Foresters National Convention; 1986 Oct 5; Birmingham, AL. : 138-143.

Often water quality management is viewed as a cost with no financial return for the investment, but protecting water quality for fisheries can have positive economic returns to the forest landowner. Many of the practices used to protect water quality are the same ones done to protect or improve soil productivity. Protecting or improving soil productivity means more timber produced per acre, which is translated into economic returns to the landowner. Also, erosion and sediment control practices can save in road construction and maintenance costs.

50. Douglass, J. E. Watershed Values Important in Land Use Planning on Southern Forests. Journal of Forestry. 1974: 617-621.

Forests cover 20 to 65 percent of the land in the major water resource regions of the South, and forest management practices control or regulate the volume and timing of streamflow from these lands. Although water quality is emerging as the major water problem, quantity and timing of streamflow are also important and interrelated watershed values which should be considered in land use planning. Protection or improvement of hydrologic performance of forest soils will continue to be an important consideration in planning.

51. Douglass, J. E.; Goodwin, O. C. Runoff and Soil Erosion From Forest Site Preparation Practices. In: Proceedings U.S. Forestry and Water Quality: What Course for the 80s? An Analysis of Environmental Issues. Richmond, VA: Water Pollution Control Association; 1980: 50-74.

Soil losses and runoff were measured for three years after mechanical site preparation treatments were applied on 16 small watersheds in the North Carolina Piedmont. Treatments consisted of control (undisturbed forest), KG Only, KG and Disk, and KG, Disk, and Plant Grass replicated at four locations. Data were analyzed by regression techniques. Runoff increased with intensity of treatment and could be predicted from the total length of the ephemeral drainage network. Soil loss varied with percent ground cover and runoff. Once runoff differences were accounted for, the only variable of importance in predicting soil loss in pounds per inch of runoff was percent cover. Erosion varied from as little as 1.0 to as much as 14,000 pounds per acre, depending on cover and ephemeral channel network.

52. Douglass, J. E.; Swank, W. T. Effects of Management Practices on Water Quality and Quantity: Coweeta Hydrologic Laboratory, North carolina. : USDA Forest Service; 1975; General Technical Report NE-13. 1-13.

Results from nearly 40 years of watershed experiments at Coweeta are summarized. An equation is presented to predict the annual increase in streamflow from the percent basal area cut and from the theoretical extra-terrestrial radiation load for the watershed. Timing of the increased flow from watershed experiments depends on the magnitude of the increase, but results consistently show that much of the increase appears in the low-flow season. Two watershed experiments indicate that conversion of hardwoods to white pine substantially reduces monthly and annual streamflow. Conversion of a hardwood covered watershed to grass produces up to 5.8 inches of increased flow per year. Although some increase in nutrient export occurs from forest cuttings and species conversions, the increase is well within drinking-water standards.

53. Douglass, J. E.; Swank, W. T. Streamflow Modification Through Management of Eastern Forests. : USDA Forest Service; 1972; Research Paper SE-94. 15p.
Note: have it.

Equations for predicting the first-year yield increase, duration of the increase, and the total volume of water which occurs from cutting forests are presented. The equations are based on a summary of 22 experimental cuttings of hardwood forests in the Appalachian Highlands. Predicted yields are compared with actual yields obtained from a logged watershed. The paper also discusses the effects of forest cutting on the seasonal distribution of increased annual flow, stormflow peaks and volumes, and water quality characteristics.

54. Douglass, J. E.; Van Lear, D. H. Prescribed Burning and Water Quality of Ephemeral Streams in the Piedmont of South Carolina. Forest Science. 1983; 29(1): 181-189.

Soil and nutrient export were monitored before and after two prescribed burns 18 months apart. Burns were designed to prepare Piedmont pine stands for regeneration. Data from four pairs of treatment and control watersheds were analyzed as a randomized complete block experiment. The burns did not significantly affect storm runoff, sediment concentrations, or sediment export from the watersheds. Both runoff and sediment export increased from one watershed, but the effect was due to a bark beetle outbreak rather than to prescribed burning. Analysis showed no significant change in NO3-N, NH4-N, Ca, Mg, or K concentrations or export after either burn. Sodium concentration before burning was significantly different for the burned-unburned watershed pairs but not significant after either precribed burn. This difference was attributed to factors other than burning. It was concluded that the two prescribed burns did not change water quality of the streams studied.

55. Douglass, James E.; Swank, Wayne T. Effects of Management Practices on Water Quality and Quantity: Coweeta Hydrologic Laboratory, North Carolina. Municipal Watershed Management Symposium Proceedings. : USDA Forest Service, Institute for Research on Land and Water Resources, The Pennsylvania State University, New Hampshire Water Resources Research Center, University of New Hampshire; 1975; General Technical Report NE-13: 1-13.

Results from nearly 40 years of watershed experiments at Coweeta are summarized. An equation is presented to predict the annual increase in streamflow from the percent basal area cut and from the theoretical extra-terrestrial radiation load for the watershed. Timing of the increased flow from watershed experiments depends on the magnitude of the increase, but results consistently show that much of the increase appears in the low-flow season. Two watershed experiments indicate that conversion of hardwoods to white pine substantially reduces monthly and annual streamflow.

Conversion of a hardwood-covered watershed to grass produces up to 5.8 inches of increased flow per year. Although some increase in nutrient export occurs from forest cuttings and species conversions, the increase is well within drinking-water standards.

56. Douglass, James E.; Swank, Wayne T., Principal Hydrologist and Principal Plant Ecologist (Coweeta Hydrologic Laboratory; Southeastern Forest Experiment Station). Multiple Use in Southern Appalachian Hardwoods - A 10-year Case History. : USDA Forest Service; 1976 Jan 2. 425-436.

The multiple-use concept of managing hardwood forests in the southern Appalachians for timber, water, wildlife, and recreation was pilot-tested on a 144-ha watershed in western North Carolina. Water, timber, and wildlife objectives of management were achieved, and responses of these resources during the first 10 years of management are discussed. Log dams designed to create riffles and pools caused the greatest conflict with other objectives by increasing turbidity of water, causing excessive channel and bank cutting, and probably adversely affecting trout, at least temporarily.

57. Dyer, K. L.; Curtis, W. R. pH in Streams Draining Small Mined and Unmined Watersheds in the Coal Region of Appalachia. : USDA Forest Service, Northeast Forest Experiment Station; 1983; Research Note NE-314. 6p.

To better evaluate the effects of surface mining for coal in first-order watersheds in Appalachia, a network of 421 water quality sampling stations was established in 136 counties in nine states in 1977 and sampled on approximately a monthly basis until August 1979. Three categories of watersheds were sampled: (1) unmined, (2) mined after January 1972, and (3) mined before January 1972. Mean pH values averaged 7.0, 6.7, and 6.3 for these three categories of watersheds, respectively.

58. Ebert, Danny J.; Nelson, Thomas A.; Kershner, Jeffery L., Fisheries Program Manager; Associate Professor; National FHR Coordinator (USDA Forest Service; Arkansas Tech University; USDA Forest Service). Warmwater Fisheries Symposium I; 1991 Jun 4; Phoenix, Arizona. : 217-224. (. v. USDA Forest Service, General Technical Report RM-207).

Fish, habitat, and water quality data were collected during low flow conditions in 16 Louisiana coastal plain streams for two consecutive years. Stream habitats consisted of pools and flats, and were characterized by fine sediment and sand substrate. Five distinct land/aquatic or soil dominated stream types were delineated and evaluated for fish numbers and biomass, species richness and habitat diversity. Fish biomass, total fish numbers and species richness were correlated with soil type, stream gradient, habitat diversity, and pool volume. Stream reaches in mixed, kisatchihe, and sandy soils contained higher fish biomass and numbers than other sample streams. Within these reaches pool volume was most significant among 34 habitat variables measured and analyzed. Woody debris formed pools and channel bend pools contained the majority of fish species. Stream reaches within sandy and flat soils were dominated by long stretches of shallow flats. Dominant fish species inhabitating flats by total numbers and biomass were lamprey ammeocetes (Ichthymyzon spp.) madtom catfish (Noturus nocturnus and N. phaeus), and shiners (Notropis sabinae, N. venustus, and N. chrysocephalus isolepis). Pirate perch (Aphrododers sayanus), longear sunfish (Leopmis megolitis, spotted bass (Micropterus punctulatus), and blackspotted killifish (Fundulus olivaceus) dominated pools by total numbersl. Larval lamprey, madtom catfish, and shiners accounted for more than 89 percent of fish biomass.

59. Eschner, Arthur R.; Larmoyeux, Jack. Logging and trout: Four experimental forest practices and their effect on water quality. Progressive Fish-Culturist. 1963; 25: 59-67.

Experimental logging of watersheds caused significant changes in quantity and quality of streamflow. Poorly located and constructed skid-roads resulted in continuous, very high stream turbidities during logging. This effect diminished with time after logging disturbance ended. Carefully planned and constructed skidroads contributed negligible amounts of turbidity. Clearcurring resulted in significantly higher maximum stream temperatures in the growing season, lower minimum temperatures in the dormant season. Maximum stream temperatures above those generally tolerated by brook trout were noted often in the summer of 1959. Moderate cutting did not produce water-quality changes that might be harmful to trout. Increases in Ph, alkalinity, and specific conductance were noted in the stream flowing from the clearcut watershed. Streamflow was increased by the treatments in proportion to the amount of timber cut and killed. Most of the increases came late in summer and early fall, in periods of high evapotranspiration and soil moisture recharge, when flow in many trout streams is dangerously low. Changes in stream pH, alkalinity, and temperature are persisting; but treatment effects on quantity of flow and turbidity are diminishing as time passes.

60. Everest, F. H. Anadromous Fish Habitat and Forest Management Economic Considerations. Proceedings of the Western Association of Fish and Wildlife Agencies and Western Division of the American Fisheries Society .; 1978: 58th Annual Conference; Corvallis, Oregon. Pacific Northwest Forest and Range Experiment Station: USDA Forest Service; 1978: 153-171.

Fish and timber are important products of forests and are managed concurrently in many watersheds. But fishery resources are seldom managed at levels commensurate with their importance because their economic values are unknown. No existing procedures for evaluating sport fisheries are completely adequate or universally accepted, nevertheless, estimates of value can be made with existing technology and even these can be useful to forest managers. Once fishery values are established, components of fish habitat can be evaluated and benefit/cost analyses can be conducted on proposed forest management activities, land use plans, and fish habitat improvement projects. Tentative analyses reveal that increased investment in forest management for protection of fish habitat can be justified economically.

61. Fisher, R. F. Impact of Intensive Silviculture on Soil and Water Quality in a Coastal Lowland. In: Lal, R.; Russell, E. W., eds. Tropical Agricultural Hydrology. London: John Wiley and Sons; 1981: 299-309.

The hope of many forestry organizations in the tropics is to convert natural forest to highly productive domesticated forests of fast growing species. The experience of declining productivity in second and subsequent rotations of domesticated forests in Australia (Florence, 1967) has caused us to become concerned that such a fate might befall similar forests in the tropics. To study this we have isolated some experimental watersheds in the coastal lowlands of Florida.

62. Flathead Basin Commission. Flathead Basin Forest Practices Water Quality and Fisheries Cooperative Program - Final Report. : Flathead Basin Commission; 1991. 215p.

This is the Final Report summarizing ten individual studies conducted for the Flathead Basin Forest Practices/Water Quality and Fisheries Cooperative Program. The Cooperative Program was administered by a Coordinating Team representing the Montana Department of State Lands Forestry Division, the Flathead National Forest, Plum Creek Timber Company, L.P., the Montana Department of Fish, Wildlife and Parks, the Montana Department of Health and Environmental Sciences' Water Quality Bureau, the University of Montana, and the Flathead Basin Commission. The Cooperative Program's specific objectives were (1) to document, evaluate, and monitor whether forest practices affect water quality and fisheries within the Flathead Basin, and (2) if detrimental impacts exist, to establish a process to utilize this information to develop criteria and administrative procedures for protecting water quality and fisheries. The ten individual studies included the evaluation of: (1) specific practices at the site level, (2) accumulation of practices at the watershed level, (3) general stream conditions, (4) water quality variable relative to levels of management activity in small watersheds, (5) fish habitat and abundance relative to stream variables influenced by forest practices at the watershed level, (6) long-term changes in large-stream dynamics related to historical records of natural and man-related disturbances, and (7) changes in lake sediments relative to historical records of natural and man-related disturbances.

63. Florida Department of Agriculture and Consumer Services. Silvicultural Best Management Practices Manual. : Florida Department of Agriculture and Consumer Services, Division of Forestry; 1990. 76p.

It has been documented that certain forestry practices on sensitive sites impact water quality. This manual discusses these impacts, the management practices that may cause them, and the management techniques used to prevent or minimize them. The manual provides a brief discussion of the silviculture/water relationship in Florida as it is currently understood, and offers recommendations that, if followed, will protect surface water quality and conserve site productivity. It describes the method being used to match Best Management Practices with various forest conditions in Florida, the Best Management Practices themselves, the method to be used to evaluate both compliance and Best Management Practice effectiveness, and the available sources of technical assistance.

64. Fowler, W. B.; Anderson, T. D.; Helvey, J. D. Changes in Water Quality and Climate After Forest Harvest in Central Washington State. : USDA Forest Service, Pacific Northwest Research Station; 1988; Research Paper PNW-RP-388. 12p.

Chemical output of nitrate, calcium, magnesium, sodium, potassium, and organic nitrogen were determined on a grams-per-hectare-per-day basis for five treatment watersheds and a control watershed. Water samples were collected from April to October during 3 pretreatment and 3 posttreatment years (1978 to 1983). Except for increased calcium and sodium in several streams, regression equations comparing treatment with control showed no significant difference for pretreatment and posttreatment output. Output generally declined in the posttreatment years. Cyclic changes in output from these and other streams in the eastern Cascade Range in Washington appeared to occur regardless of treatment and were probably related to precipitation. Mean maximum air temperature increased during the posttreatment period in all the small watersheds, but stream temperatures were relatively unaffected.

65. Fowler, William (Principal Meteorologist, Pacific Northwest Forest & Range Experiment Station, Wenatchee, Washington). The Use of Biological Indicators as an Index of Stream Health. Baumgartner, David M. Interior West Watershed Management; 1909 Apr 8; Spokane, Washington. Washington State University: Washington State University, Cooperative Extension; 1981: 70-80.

There is a substantial literature on the use of aquatic organisms as indicators of stream water quality. Among these organisms are the resident and transient bacteria, benthic macroinvertebrates, periphyton (attached communities of microorganisms), macrophyton, and the fishes. Recently, because of public health concern, enteric viruses and some protozoans have been added to this list. As indicators, the benthic macroinvertebrates are probably the best known and most frequently used. They and the periphyton, being relatively immobile, provide an integrated response to the environmental influences at their location. A definition of stream "health" is considered that reflects the structure and functioning of the aquatic ecosystem. Qualitative expressions and quantitative measures useful in this definition are noted to have both disadvantages and advantages. Several examples of stream health are provided which illustrate the sensitivity of the biological organisms to imposed stress.

66. Fredriksen, R. L. Comparative Chemical Water Quality: Natural and Disturbed Streams Following Logging and Slash Burning. In: Krygier, J. T.; Hall, J. D., Directors. Forest Land Use and Stream Environment. Corvallis, OR: Oregon State University; 1971: 125-137.

The loss of nutrients from an old-growth Douglas fir forest was measured in the streams of experimental watersheds. Following timber harvest and slash burning, loss of nutrients cations increased 1.6 to 3.0 times the loss from the undisturbed watershed. A surge of nutrients that followed broadcast burning contained concentrations of ammonia and manganese that exceeded Federal water quality standards for a period of 12 days. Annual nitrogen loss following burning averaged 4.6 pounds per acre; 53% of this was organic nitrogen contained in sediment. Inorganic nitrogen, dissolved in the stream, made up the remaining part. Annual loss of nitrogen from the undisturbed forest was very small - .16 lb/ac.

67. Georgia Forestry Association, Wetlands Committee. Best Management Practices for Forested Wetlands in Georgia. : Georgia Forestry Commission; 1990. 26p.

Georgia's forests provide a tremendous variety of goods and services for the people of the state and region. If properly managed, using good conservation practices and techniques; these forests can provide continued and improved benefits, even with the pressures of increased population and urbanization. Wetlands have been recognized as one of the nation's important resources. Wetlands are those areas that are inundated or saturated by surface or ground water at a frequency and duration sufficient to support, and that under normal circumstances do support, a prevalence of vegetation typically adapted for life in saturated soil conditions. Georgia's forested wetlands are an important component of the state's forests. The South's Fourth Forest Report identifies 3.5 million acres of bottomland hardwood in Georgia. In addition, portions of several other forest types are classified as wetlands. These wetlands have many functions and values, among which are: water quality, timber production, fish and wildlife habitat scenic beauty, recreation, education and research. The original Recommended BMPs for Forestry in Georgia were prepared to inform loggers, foresters, landowners, and others involved in forestry about simple, practical methods to minimize erosion from forest operations. These practices are economical and effective measures for ensuring forestry's contribution to a high standard of water quality in Georgia. The use of Best Management Practices (BMPs) for forest road construction and maintenance is mandated by federal legislation to qualify for the silvicultural exemption from the permit process provided for in the 1972 Water Pollution Control Act and Clean Water Act Amendments of 1977, and 1987. Federal legislation's basic goal is to protect and enhance the quality of the nation's waters so they are fishable and swimmable. The use of BMPs enables these goals to be met on waters influenced by forest lands. These Best Management Practices have been developed by a task force representing a wide range of interests in forested wetlands. Properly and carefully implemented, BMPs will protect and enhance important wetlands functions on most sites under most weather conditions while allowing economic silvicultural operations. Some wetlands sites are not suitable for commercial timber production. On extremely sensitive sites or in extremely severe weather conditions, more stringent measures may be required. These BMPs are designed and intended for silvicultural operations where sustained timber production is one of the landowner's objectives. Normal silvicultural activities such as plowing, the placement of soil bedding for seed or seedlings, minor drainage and harvesting as a part of established silvicultural operations are exempt from Section 404, Permit Requirements, 40 CFR Section 232. Discharge of fill materials into waters of the United States from ditching, or other activities whose purpose is to convert forested wetlands to some other use (i.e., silviculture to agriculture or real estate), where the flow or circulation of the waters may be impaired or the reach reduced; is not permitted under the silvicultural exemptions of the Clean Water Act. Landowners intending a land use change such as to agricultural production or real estate development should consult with local authorities, the Georgia Department of Natural Resources and the U.S. Army Corps of Engineers prior to initiating operations. Most of these operations may require general or individual permits. Forestry representatives must implement the use of BMPs. It is the forester's duty to plan, and properly supervise operations so water quality is not compromised. Violation of the standards will invite government intervention and the imposition of mandatory BMPs, permits, fines, and other constraints. These forested wetlands BMPs should be used in conjunction with the "Recommended Best Management Practices for Forestry in Georgia". This publication is available from the Georgia Forestry Commission.

68. Gibbons, D. R.; Salo, E. O. An annotated bibliography of the effects of logging on fish of the western United States and Canada. Pacific Northwest Forest and Range Experiment Station: USDA Forest Service; 1973; General Technical Report No. PNW-10. 145p.

Contains 278 annotated references arranged in 10 sections: Erosion and sedimentation; Streamside vegetation; Water quality; Alteration of streamflow; Descriptions of effects of logging studies; Related salmonid information; Multiple logging effects; Stream protection; Stream improvement; and Multiple-use management. A further 39 unannotated references are given, and also subject and author indexes, and a brief review of the literature on logging and fisheries.

69. Gibbons, D. R.; Salo, E. O. An Annotated Bibliography of the Effects of Logging on Fish of the Western United States and Canada. : USDA Forest Service; 1973; General Technical Report PNW-10. 145p.

This bibliography is an annotation of the scientific and nonscientific literature published on the effects of logging on fish and aquatic habitat of the Western United States and Canada. It includes 278 annotations and 317 total references. Subject areas include erosion and sedimentation, water quality, related influences upon salmonids, multiple logging effects, alternation of streamflow, stream protection, multiple-use management, streamside vegetation, stream improvement, and descriptions of studies on effects of logging. A review of the literature, a narrative on the state of the art, and a list of research needs determined by questionnaires are included.

70. Glasser, S. P. Summary of Water Quality Effects from Forest Practices in the South. Atlanta, GA: USDA Forest Service Southern Region; 1989. 50p.
Note: have it.

The results of many watershed research studies within the 13 States comprising the Southern Region of the USDA Forest Service are summarized for their reported effects of common forest management practices on water quality. The results are grouped by Major Land Resource Areas. Sediment yields from forested basins in the Southeast are typically less than 0.25 ton per acre per year under undisburbed conditions, but can rise to 100 times this amount for brief periods following poorly conducted logging and road building operations. Recovery to pre-disturbance levels takes less than three years. A number of Best Management Practices (BMP's) are shown to minimize damage to water quality. Some changes in chemical concentrations and export in streamwater have been noted in research studies, particularly in the mountains. Small increases in potassium and nitrates have been most common, but are thought to represent no ecological threat to aquatic communities. Forest insect pest epidemics can also cause increases in water nitrate-nitrogen concentrations. Monitoring of commonly used forest herbicides has shown they pose no threat to aquatic plants, insects or fish when applied correctly. They also breakdown in forest soils very rapidly.

71. Goetzl, A.; Siegel, W. C. Water Quality Laws in Southern States: How They Affect Forestry. Southern Journal of Applied Forestry. 1980; 4(1): 2-11.

The Federal Water Pollution Control Act (FWPCA) as amended in 1972 and again by the Clean Water Act of 1977, has received much attention in recent years. Sections 208 and 404, in particular, have been carefully studied because they provide the primary legal framework for control of water pollution from forestry activities. By now, the forestry community is generally aware of this legislature and of its serious implications for forest management. Many practicing foresters in the South, however, appear to have little understanding of just how forestry activities have been affected by the law to date and what the potential impacts appear to be once the statute is fully implemented. Section 208 mandates that individual states develop management plans to identify and abate all sources of water pollution. It designates silvicultural activities as one source of nonpoint pollution that must be addressed. Other potential legal influences on forest practices derive from Section 404, which governs certain dredge-and-fill activities and from state-enacted water pollution control laws. The state statutes have not generally been considered in the development of 208 plans, but their importance cannot be overlooked within the legal framework surrounding the control of water pollution from forestry activities. It is too early to analyze Section 404 because at this writing the final regulations governing this section have not been implemented. This paper will thus deal with state water quality legislation and related laws in the southern states, and their relationshiip to Section 208.

72. Gold, A. J.; DeRagon, W. R.; Sullivan, W. M.; Lemunyon, J. L. Nitrate Nitrogen Losses to Groundwater From Rural and Suburban Land Uses. Journal of Soil and Water Conservation. 1990; 45(2): 305-310.

Nitrate-nitrogen (nitrate-N) losses to groundwater from septic systems, forests, home lawns, and urea- and manure-fertilized silage corn were quantified and compared during a 2-year study. The septic system and all silage corn treatments had annual flow-weighted concentrations of nitrate-N in excess of 10 mg/l for at least 1 of the 2 years. In contrast, forest and both fertilized and unfertilized home lawn treatments generated flow-weighted nitrate-N concentrations of less than 1.7 mg/l. Annual losses ranged from greater than 70 kg/ha of nitrate-N from silage corn treatments to less than 1.5 kg/ha from unfertilized home lawns and forest. The results demonstrate the importance of unfertilized land use types in maintaining aquifer water quality; they also suggest that replacing production agriculture with unsewered residential development will not markedly reduce nitrate-N losses to groundwater.

73. HACHMOELLER, B.; MATTHEWS, R. A.; BRAKKE, D. F. EFFECTS OF RIPARIAN COMMUNITY STRUCTURE SEDIMENT SIZE AND WATER QUALITY ON THE MACROINVERTEBRATE COMMUNITIES IN A SMALL SUBURBAN STREAM. Northwest Science. 1991; 65(3): 125-132.

We studied the relationships between benthic macroinvertebrates, water quality, sediment characteristics, and riparian community structure in Padden Creek, a second-order stream in Bellingham. Washington, to look for patterns in the macroinvertebrate community structure between upstream and downstream sites. Padden Creek was sampled at four sites; one site was densely forested and relatively unpolluted, while the remaining sites were affected to various degrees by channelizaiton, deforestation, and nonpoint source pollution. We measured water quality (including nutrients), sediment structure, riparian vegetation, and benthic macroinvertebrate densities at each site between 14 May and 1 October 1989. Many taxa were more abundant at the undisturbed, forested upstream site (Site 1), especially pollution intolerant mayflies, stoneflies, and caddisflies. At Site 2, where the surrounding forest had been cleared, there was a decrease in the density of shredders, predators, and collector-filteres, and an increase in scrapers. At Sites 3 and 4, where the stream is affected by organic pollution, there were fewer representatives from pollution intolerant orders (Ephemeroptera, Pleceoptera, and Trichoptera) and many more non-insect taxa (e.g., oligochaetes and gastropods). Thus, the effects of channelization, deforestation, and pollution resulted in major changes in the structure of macroinvertebrate communities at downstream sites, suggesting that such riparian alterations imitiate similar urbanization effects of high-order rivers.

74. Hachmoller, B.; Matthews, R. A.; Brakke, D. F. Effects of Riparian Community Structure, Sediment Size, and Water Quality on the Macroinvertebrate Communities in a Small, Suburban Stream. Northwest Science. 1991; 65(3): 125-132.

We studied the relationships between benthic macroinvertebrates, water quality, sediment characteristics, and riparian community structure in Padden Creek, a second-order stream in Bellingham, Washington, to look for patterns in the macroinvertebrate community structure between upsteam and downstream sites. Padden Creek was sampled at four sites; one site was densely forested and relatively unpolluted, while the remaining sites were affected to various degrees by channelization, deforestation, and nonpoint source pollution. We measured water quality (including nutrients), sediment structure, riparian vegetation, and benthic macroinvertebrate densities at each site between 14 May and 1 October 1989. Many taxa were most abundant at the undisturbed, forested upstream site (Site 1), especially pollution intolerant mayflies, stoneflies, and caddisflies. At Site 2, where the surrounding forest had been cleared, there was a decrease in the density of shredders, predators, and collector-filterers, and an increase in scrapers. At Sites 3 and 4, where the stream is affected by organic pollution, there were fewer representatives from pollution intolerant orders (Ephemcroptera, Plecoptera, and Trichoptera) and many more non-insect taxa (e.g., oligochaetes and gastropods). Thus, the effects of channelization, deforestation, and pollution resulted in major changes in the structure of macroinvertebrate communities at downstream sites, suggesting that such riparian alterations imitate similar urbanization effects of higher-order rivers.

75. Harr, R. D. Myths and Misconceptions About Forest Hydrologic Systems and Cumulative Effects. In: Proceedings of the California Watershed Management Conference. : Wildland Resources Center, University of California, Berkley; 1987; Report 11. 167p.

Among the various documents that have affected the management of Federal forest lands, perhaps the two most important from the standpoint of forest planning are the National Forest Management Act of 1976 (NFMA) (USDA Forest Service 1979) and the National Environmental Policy Act of 1970 (NEPA) (Council of Environmental Quality 1978). NFMA details how USDA Forest Service is to plan its forest management activities, while NEPA requires environmental assessments or environmental impact statements for planned activities. The current concern over cumulative effects of logging activities can be traced directly to the regulations for implementing NEPA. Water specialists on interdisciplinary planning teams have been directed to formulate guidelines, determine thresholds, and construct methodologies that can be used to address cumulative effects of proposed activities on soil and water resources. Specialists from USDA Forest Service and USDI Bureau of Land Management in western Oregon, western Washington, and northern California have been contacting me, and probably other research hydrologists, in search of the elusive thresholds. In my efforts to provide assistance, I have become aware of a number of myths and misconceptions that are circulating freely among watershed specialists and others concerned with forest management as they look for simple, predictive tools. The object of this paper is to discuss several of the myths and misconceptions as I see them.

76. Harr, R. Dennis. Scheduling timber harvest to protect watershed values. In: Baumgartner, David M., compiler/editor. Interior West Watershed Management; 1980 April 8-10; Spokane, Washington. Pullman, Washington: Washington State University Cooperative Extension; 1981: 269-280. 288 pages.

The USDA Forest Service is attempting to develop techniques for incorporating watershed values into the planning process described by the National Forest Management Act of 1976. A recent workshop on scheduling harvesting for soil and water concerns revealed several problems associated with the development of such techniques. These problems include: determining the effectiveness of harvest scheduling for protecting soil and water resources, distinguishing adverse effects caused by how and if an activity is done from effects caused by when it is done; and judging the reliability of predictions we can currently make on how harvest activities affect peak stream discharge and sediment routing. Procedures now used to estimate impacts of harvest activities on soil and water resources have weaknesses that limit their usefulness in scheduling harvest to protect soil and water resources.

77. Harr, R. D.; Fredriksen, R. L.; Rothacher, J. S. Changes in Stream Flow Following Timber Harvest in Southwestern Oregon. Pacific Northwest Forest and Range Experiment Station, Portland, OR: USDA Forest Service; 1979; Research Paper PNW-249. 22p.

Shelterwood cutting and small patch clearcutting have been proposed to overcome problems of reforestation in the mixed-conifer zone of south-western Oregon. In 1962, a study was begun to determine changes in quantity and quality of streamflow following these two harvest methods and to compare them with changes caused by complete clearcutting. Specifically, the objectives of this study are to determine increases in size of annual yield, seasonal yield, and peak streamflow after timber harvest. This report describes changes in streamflow following the first of three phases of timber harvest. Water quality changes will be described in a subsequent report.

78. Hartman, G. Proceedings of the Carnation Creek workshop, a 10 year review; 1982 Feb 24; Malaspina College, Nanaimo, B.C. : Pacific Biological Station; 1983. 404p.

Nineteen papers were presented on the effects of different logging operations on the soils, vegetation and, principally, water quality and fish populations of the Carnation Creek catchment, a coastal hemlock and cedar forest zone near Bamfield on Vancouver Island. A special study of this catchment was begun in 1970, planned in three phases, pre-logging 1970-1975; logging 1975-1981 and post-logging, 1981-1985.

79. Harvey, G.; Hess, S.; Jones, L.; Krutina, D.; McGreer, D.; Reid, W.; Stockton, D.; Thornton, J. Final Report: Forest Practices Water Quality Audit - 1988. Boise, ID: Idaho Department of Health and Welfare, Division of Environmental Quality; 1989.

EXECUTIVE SUMMARY: Forty projects were audited; 10 Forest Servive, 10 Deparment of Lands, 10 forest industry, and 10 private non-industrial. The audit team was composed of representatives of land management agencies, regulatory agencies and private industry with expertise in fisheries biology, hydrology, forestry, forest road construction and water quality. A representative of conservation groups was invited, but the offer was declined due to the extensive time required for the audits. Audited projects were selected from pools of projects which met criteria established by the audit team. The most critical criteria assured the close proximity of the activity to a protected fishery or domestic water supply and the potential for nonpoint source pollution. The Forest Practices Audit was conducted to answer the following specific questions: Were the BMPs applied by the agencies and operators? Were the BMPs effective in preventing sediment production? Have pollutants been delivered to the stream or potentially could they be? Are there any implementation problems with the BMPs? Are there any BMP implementation problems specific to land ownwership category?

80. Harvey, Geoff; Hess, Scott; Jones, Larry; Krutina, Dan; McGreer, Dale; Reid, Will; Stockton, Don; Thornton, John (Idaho Dept. of Health & Welfare Div. of Env. Quality; Intermountain Forest Industries Assoc.; Idaho Dept. of Lands; U.S. Forest Service Region 1; Intermountain Forest Industries Assoc.; Idaho Dept. of Fish & Game; Idaho Dept. of Lands; U.S. Forest Service Region 4). Final Report: Forest Practices Water Quality Audit - 1988. Water Quality Bureau Report. Boise, Idaho: Idaho Dept. of Health & Welfare; 1989 Apr. 26 Pages plus Appendices A-E.

Forty projects were audited; 10 Forest Service, 10 Dept. of Lands, 10 forest industry and 10 private non-industrial. The audit team was composed of representatives of land management agencies, regulatory agencies and private industry with expertise in fisheries biology, hydrology, forestry, forest road construction and water quality. A representative of conservation groups was invited, but the offer was declined due to the extensive time required for the audits. Audited projects were selected from pools of projects which met criteria established by the audit team. The most critical criteria assured the close proximity of the activity to a protected fishery or domestic water supply and the potential for non-point source pollution. The Forest Practices Audit was conducted to answer the following specific questions: -Were the BMPs applied by the agencies and operators? -Were the BMPs effective in preventing sediment production? -Have pollutants been delivered to the stream or potentially could they be? -Are there any implementation problems with the BMPs? -Are there any BMP implementation problems specific to land ownership category? Projects were examined by walking roads, skid trails and streams. Compliance with BMPs was determined. Soil erosion surfaces and actual or potential pathways by which eroded materials could be transported to the streams were identified. Class I streams were examined to assess their water quality condition and the impact of the project. Results and Recommendations: BMP COMPLIANCE: Compliance with the BMPs was high on federal, state and forest industry projects, averaging 95% of the opportunities to apply BMPs. Compliance on non-industrial private projects was 86%. Where the BMPs were not applied pollutants were delivered to waters in 70% in the cases. BMP EFFECTIVENESS: The audit team did not observe any pollutants delivered to streams in 99% of the cases where the BMPs were applied.

81. Hawks, L. J. Forest Water Quality Protection: A Regional Study of the Chesapeake Bay. Athens, GA: School of Forest Resources, University of Georgia; 1991; M.S. Thesis. 110p.

Primarily policy oriented paper - compares Virginia's voluntary program with Maryland's regulatory program in success of protecting water quality.

82. Hedman, C. W.; Van Lear, D. H. Large Woody Debris Contributions From Riparian Zones: Current Knowledge and Study Description. In: Proceedings of the Sixth Biennial Southern Silvicultural Research Conference.; 1930 Oct; Memphis, TN. Asheville, NC: USDA Forest Service, Southeastern Forest Experiment Station; 1991; General Technical Report SE-70: 681-687.

The ecological role that riparian zones play in contributing large woody debris (LWD) to streams has been investigated in the Pacific Northwest and Northeast, but represents a major gap in knowledge of forest ecosystem functions in Southern Appalachian watersheds. Riparian zone vegetation is a source of LWD for streams which influences stream ecology and morphology. In this study, riparian zones representing a sere from early successional through old-growth forests are being investigated to obtain quantitative/qualitative baseline data regarding the attributes of Southern Appalachian riparian zones and in-stream LWD. Characterization of LWD inputs will provide needed information for forest managers, fisheries biologists, and water resource specialists as management of riparian zones becomes increasingly important in enhancing forest diversity, resource quality and productivity.

83. Helvey, J. D.; Tiedemann, A. R.; Fowler, W. B. Some climatic and hydrologic effects of wildfire in Washington State. In: Proceedings, Tall Timbers Fire Ecology Conference 1974; Pacific Northwest Forest and Range Experiment Station, Wenatchee, Washington. : USDA Forest Service; 1976; No. 15: 201-222.

Pre- and post-fire measurements are reported for three watersheds burned by wildfire in August 1970. Streamflow increased dramatically after destruction of vegetation. Snowmelt runoff commenced earlier and runoff peaks were higher after the fire. No effects of fire on the subsequent fertilization for erosion control and on water quality for municipal uses were detected. The concentrations and losses of cations and more particularly nitrate-N increased considerably but soil nutrient reserves were not seriously affected. Stream temperatures increased after channels were exposed to sunlight but remained within the range recommended for trout. Midday heating and nocturnal cooling of soil and various plant residues and inorganic materials was recorded in June. Charred plant remains were largely responsible for high surface temperatures; this effect was moderated not only by vegetation regrowth but also by the disturbance due to logging.

84. Henderson, G. S. Nutrient Dynamics in Disturbed Forests and Associated Influences on Stream Chemistry. In: Blackmon, B. G., ed. Proceedings of Forestry and Water Quality: A Mid-South Symposium.; 1985 May 8; Little Rock, AR. : University of Arkansas; 1985: 55-65.

Recent theories on factors controlling nutrient dynamics in southern pine and hardwood stands are examined relative to dissolved nutrient discharge to streams and ground water. Nutrient discharges due to forest disturbance are universally low and this is undoubtedly coupled to slow nitrification rates. Riparian zones have been found to alter surface runoff chemistry and those with forested buffer strips appear to be more effective in retaining dissolved nutrients.

85. Hetherington, E. D. Carnation Creek, Canada: Review of a West Coast Fish/Forestry Watershed Impact Project. in: Forest Hydrology and Watershed Management. Institute of Hydrology, Wallingford, Oxfordshire, UK: International Association of Hydrological Sciences Press; 1987; IAHS Publication No. 167: 531-538.

Carnation Creek is a small, rainforest salmon stream located on the west coast of Vancouver Island, British Columbia. In 1970, a 16-yr multi-agency and multi-disciplinary project was initiated to evaluate the effects of logging and silvicultural activities on the Carnation Creek watershed and communicate the results to managers of forests and fish. The nature and results of the project are reviewed, including a discussion of the transfer of research findings, their application by resource managers, and the significance of the project for fishery and forestry management in coastal British Columbia. Peak flows and water yield increased in a small tributary, groundwater levels were higher and there were minor changes in water quality. There were also major changes in stream channel and organic debris structure, deterioration of fish habitat and spawning gravel quality and a complex variety of effects on fish growth and survival.

86. Hewlett, J. D. Forest Water Quality: An Experiment in Harvesting and Regenerating Piedmont Forest. Athens, GA: School of Forest Resources, University of Georgia; 1979; A Georgia Forest Research Paper. 22p.

87. Hewlett, J. D.; Fortson, J. C. Stream Temperature Under an Inadequate Buffer Strip in the Southeast Piedmont. Water Resources Bulletin. 1982; 18: 983-988.

A paired watershed experiment on the southeastern Piedmont to determine the effect of clearcutting loblolly pine on water quantity, quality, and timing has shown that stream water temperatures were increased as much as 20 degrees F even though a partial buffer strip of trees and shrubs were left in place to shade the stream. Winter time minimum stream temperatures were lowered as much as 10 degrees F by the same treatment. A stream temperature model now in use did not predict such elevated temperatures. The authors suggest that forest cover reductions in areas of gentle land relief may elevate the temperature of shallow ground water moving to the stream, even with a substantial buffer strip in place.

88. Hickman, Clifford A., Economist (USDA Forest Service, Southern Forest Experiment Station, New Orleans, LA). Cost-Effectiveness of Forestry Nonpoint Source Pollution Control Measures. in: U.S. Forestry and Water

Quality: What Course in the 80's; 1980 Jun 19; Richmond, VA. Washington, DC: Water Pollution Control Federation: 162-179.

The 1972 Federal Water Pollution Control Act Amendments (P.L. 92-500) stipulate that, if forestry activities are contributing to a water pollution problem, control measures are to be initiated to the extent feasible. To comply with this directive water quality planners and forest managers will have to answer two basic questions. The first is: What means of control should be employed? The second is: What degree of control should be sought? This paper addresses these questions by examining two analytical techniques: "benefit-cost analysis" (B/C analysis) and "cost-effectiveness analysis" (C/E analysis). The decision to limit the discussion to these procedures reflects a basic premise of the paper -- namely, that questions about the imposition of pollution controls are essentially economic questions that will be most effectively answered by using the tools of economic analysis.

89. Hobbs, D.; Halbach, T. Streamside management zone inventory. Olympia, WA: Washington State Department of Ecology; 1981; Report No. DOE 81-12. 106p.

Streamside clear-felled areas in Washington, where the State Forest Practice Board has defined streamside management zones (SMZ - 50 ft along large highly used streams and 25 ft along small streams) in which particular attention is to be given to protecting water quality. At 12 sites there was very little harvesting in the SMZ but at 13 there were very few remaining trees and shrubs. Wildlife ratings were low where vegetation removal was extensive. Channel stability was reduced by tree and shrub removal from the upper banks. Increased water temp. occurred at 2 streams where shade-producing vegetation had been removed. Windthrow had occurred at 25 streams and was anticipated to give long-term ecological benefits. Small streams were consistently rated lower than large ones. It is suggested that all non-merchantable trees and vegetation be left in the SMZ and that the zone should also operate to protect fish and wildlife.

90. Hollis, Charles W. (U. S. Army Corps of Engineers). The Evolution and Current Status of Section 404 for Southern Forests. The Status of Forestry Management-Related Water Quality Protection Regulatory Programs. New York, New York: National Council of the Paper Industry for Air and Stream Improvement; 1982; Technical Bulletin 389.

Section 404 of the Clean Water Act of 1977 and the regulatory program based on that Section and conducted by the U.S. Army Corps of Engineers impacts on many activities involving land use including forest and resource management. Implementation and enforcement of the Act has evolved by way of court decisions and regulation changes to its present form and will likely continue to evolve in a similar manner in the future. This discussion will briefly review the past changes in the law and the regulations and their current status. We will then look ahead to speculate what the future may hold for possible additional changes that may affect decisions by forest and resource managers.

91. Hook, J. E.; Kardos, L. T. Nitrate Leaching During Long-Term Spray Irrigation for Treatment of Secondary Sewage Effluent on Woodland Sites. Journal of Environmental Quality. 1978; 7(1): 30-34.

Two waste water-treated sites at the Pennsylvania State University Wastewater Renovation Project were monitored to measure nitrate and total N in soil water. Both long-term waste water irrigation and varied irrigation rates were examined. Soil water was sampled by porous cup samplers. The concentration of N at the 120-cm depth was taken as a measure of N which escaped the root zone and which would leach to the ground water. Recharge volume was calculated from irrigation, rainfall, and potential evapotranspiration. A hardwood forest site located on a well-drained sandy loam soil was irrigated year round with secondary municipal effluent at a rate of 5 cm/week. In the last 6 of 9 years of effluent treatment 83% of the 4,954 kg N/ha added leached from the site. Nitrate concentration in soil water at the 120-cm depth was generally > 15 mg N/liter. The hardwood forest was also ineffective in keeping nitrate concentration below 10 mg N/liter at the 120-cm depth when the 5-cm weekly application was split into two 2.5-cm irrigations or when it was lowered to 2.5 cm/week year round. An abandoned old field site planted with white spruce (Picea glauca Moench) and located on a well-drained clay loam soil was irrigated with effluent at 5 cm/week from Apr. through Nov. each year, beginning in 1963. Nitrate concentration at the 120-cm depth rarely exceeded 10 mg N/liter and only 36% of the 1,246 kg N/ha applied leached during the 6th through the 9th year of this effluent treatment. In the 10th and 11th years, when the application rate was increased to 7.5 cm/week, nitrate concentration exceeded 10 mg N/liter at the 120-cm depth, and the amount of N which leached increased to 75% of the amount applied.

92. Hornbeck, J. W. Protecting water quality during and after clearcutting. Journal of Soil and Water Conservation. 1968; 23(1).

Small forest areas in steep terrain can be clearcut without serious erosion and damage to water quality if the logging operation is carefully planned and conducted.

93. Hornbeck, J. W.; Likens, G. E.; Pierce, R. S.; Bormann, F. H. Strip Cutting as a Means of Protecting Site and Streamflow Quality When Clearcutting Northern Hardwoods. In: Bernier, B.; Winget, C. H., eds. Forest Soils and Forest Land Management: Proceedings of the Fourth North American Forest Soils Conference. Quebec, Canada: University Laval Press; 1973: 209-229.

Among the controversial aspects of clearcutting forests are the potentials for increased nutrient loss, erosion, and subsequent damage to site and stream quality (14, 20, 23). These factors are likely to remain sources of contention until more comprehensive data are available about the long-term impacts of various types of forest cutting on the total ecosystem. Currently, the Hubbard Brook Ecosystem Study in Central New Hampshire is using the small watershed technique and the ecosystem concept to learn more about the impacts of clearcutting northern hardwoods. In addition to studies of conventional clearcutting, a study was undertaken at Hubbard Brook in 1970 to determine the effects of progressive strip cutting, a form of clearcutting that is carried out in several cycles and over several years.

94. Hornbeck, J. W.; Pierce, R. S. Potential Impact of Forest Fertilization on Streamflow. In: Forest Fertilization Symposium Proceedings. : USDA Forest Service; 1973; General Technical Report NE-3: 79-87.

Forest fertilization may cause a decline in quantity of streamflow by stimulating additional leaf surface area and root occupancy, thus increasing water losses to transpiration and interception. Water quality may be affected by application of fertilizers directly into stream channels and by an increase in the amount of nutrients transported to the stream by subsurface flow. The magnitude of increases in nutrients in subsurface flow will depend on such factors as type and form of fertilizer nutrients applied, efficiency of root uptake, and water regime and cation exchange capacity of the site. The use of gaged watersheds appears to be the best method for quantifying the potential impact of forest fertilization on streamflow.

95. Hornbeck, J. W.; Reinhart, K. G. Water Quality and Soil Erosion as Affected by Logging in Steep Terrain. Journal of Soil and Water Conservation. 1964; 19: 23-27.

The influence of different forestry practices on streamflow has been investigated since 1951 on 5 forested watersheds, 38 to 96 acres in area, on the Fernow Experimental Forest in the mountains of West Virginia. The effects of cutting and logging practices on water quality are reported in this article. Practices ranged from a commercial clearcutting without regard to water values or the future value of the property, to an intensive selection cutting with careful planning and careful logging. The experiment demonstrated that excessive damage to water quality can be avoided even when logging on steep terrain. Measured maximum turbidities of streams were 56,000 ppm on the commercial clearcut area and only 25 ppm on the intensive selection cut watershed. Most of the damage to water quality occurred during and immediately after logging. Recommended forestry practices discussed include: planning of the logging operation; proper location, drainage, and grade of skidroads; and timely completion of the operation in any specific area. In most respects, practices recommended for watershed protection also contribute to the overall efficiency of the logging operation.

96. Hornbeck, James W.; Federer, C. Anthony. Effects of Management Practices on Water Quality and Quantity: Hubbard Brook Experiment Forest, New Hampshire. Municipal Watershed Management Symposium Proceedings. : USDA Forest Service Northeastern Forest Experiment Station, Darby, PA; 1975; General Technical Report NE-13: 58-65.

A hypothetical dialogue between forest hydrologists and a municipal watershed manager illustrates the knowledge gained from research at Hubbard Brook. When forest vegetation is cut, water yield increases, especially when it is most needed during critical low-flow periods in late summer and early autumn. Unless measures are taken to control regrowth, the water yield returns to pre-treatment levels within several years. The normally high quality of streams from northern hardwoods can be lowered by any reduction in vegetative cover sufficient to materially increase water yield. Nutrient leaching is accelerated after cutting and dissolved solid content of streams is subsequently increased. Erosion, sediment, and increased water temperature are also problems associated with cutting; however, they can be minimized by taking known precautions.

97. Hunter, T. K. ,. Jr; Blackburn, W. H.; Nieber, J. L.; DeHaven, M. G.; Weichert, A. T.; Awang, J. B.; Fazio, P. M.; Wood, J. C. Assessment of Nonpoint Source Pollution from Intensive Silvicultural Practices and Livestock Grazing in Southeast Forests. : Texas Agricultural Experiment Station and USDA Forest Service; 1984; Project Final Report. 140p.

The objectives of this project are: 1) to develop baseline data on stormflow and water quality from stabilized forest sites (those which have been relatively undisturbed for a period of 15-20 years); 2) to assess the impact of clearcutting and mechanical site preparation on soil erosion, stormflow and water quality; and 3) to assess the impact of livestock grazing and no grazing on soil erosion, stormflow and water quality.

98. Ice, G. G. Cumulative Effects - Concepts and Modeling of Observed Water Quality Responses. In: Forestry Management Practices and Cumulative Effects on Water Quality and Utility. : National Council of the Paper Industry for Air and Stream Improvement; 1984; NCASI Technical Bulletin No. 435. 1-14.

For the past six years, the Southern and West Coast Regional Meetings have featured one or more sessions covering research and field investigations on the impact of forestry management practices on receiving water quality and utility. This technical bulletin is an assembly of six presentations on forestry management practices and cumulative effects on water quality and utility. This concept is now receiving increasing attention for silviculture since cumulative effects must be accounted for in the planning process as a result of recent court decisions. All were presented at the West Coast Regional Meeting in 1984. The session at which these papers were presented was arranged by Dr. George G. Ice, Research Forester located at the West Coast Regional Center. In the first paper, Dr. George Ice defines the key elements of cumulative effects namely that (a) they result from two or more operations separated by space or time and

(b) single practice effects must have characteristics of persistence in order to be cumulative with the effects of other practices. Examples of how cumulative effects can be modeled and monitored and the development of a worst case analysis are presented. Dr. Arthur G. Larson, Ecosystem, Inc. then presented the highlights of the Washington State study of cumulative effects. This study was initiated at least in part because of the absence of consideration for past or future operations on adjacent lands, in review procedures of requests to carry out some forestry practices. In a review of California 208 activities, Ms. Susan O'Leary, Georgia-Pacific Corporation covered several of the more salient features of this program. Among those features reviewed was the history and final recommendations regarding cumulative effects. Dr. John G. King, USDA, then described studies in the Horse Creek basin on water quality and yield, and dealth with road erosion, sediment yield and streamflow changes. Mr. C. J. Cederholm, Washington State Department of Natural Resources described the study of effects of logging and associated activities on water quality in the Clearwater River Basin. Finally, Ms. Kathleen Sullivan, Weyerhaeuser Company, described the water quality monitoring program in the Middle Santiam River watershed designed to define the cumulative effects of forest management activities during the development of the basin for timber resources.

99. Ice, G. G. Determining the Effectiveness of Best Management Practices. In: Forest Water Quality Issues and Action Needs in the South. Workshop for Southern Region State Foresters and Cooperators; 1991 Sep 24; Nashville, TN. ; 1991.

The continuation of existing approaches to nonpoint source control is dependant on demonstrating both the effectiveness and implementation of Best Management Practices (BMPs). There are three basic requirements that must be met on any effectiveness procedure. First, there is a need to determine what water or stream quality characteristics are biologically significant? Second, it is important to determine how different management practices and site conditions influence effectiveness? Finally, public confidence in BMPs is increased when water or stream quality monitoring is conducted to provide evidence that operational projects are achieving protection goals. An example is provided of a test of the effectiveness of forest chemical BMPs in the state of Washington.

100. Ice, G. G. Dissolved Oxygen and Woody Debris: Detecting Sensitive Forest Streams. Paper Presented at: ASCE Gas Transfer, Water Surface Conference. Minneapolis, MN; 1991. 14p.

Early watershed studies showed that timber harvesting and yarding could depress dissolved oxygen in nearby streams when fresh slash entered streams and streamside shade was reduced. State forestry agencies developed rules to avoid these problems that kept fresh slash out of streams and maintained shade. New forest practice rules are designed to increase amounts of woody debris in streams for fish habitat, rejuvenating concerns about water quality and dissolved oxygen. Stream sensitivity to surface water declines in dissolved oxygen can be predicted from the reaeration coefficient, potential for oxygen demand from organic material in the stream, and potential for stream heating. A study relating the reaeration coefficient to hydraulic conditions was conducted for seven small streams in Oregon during summer and fall low flows (0.0008-0.016 m3/s) when oxygen is most likely to be depressed. Of special concern for these types of streams is the treatment of rapidly varied (nonuniform) flows and isolated pools. Maximum energy dissipation and the depth of the active stream were found to be important independent variables in predicting reaeration coefficients for these turbulent stream systems.

101. Ice, G. G. The Effectiveness of Silvicultural Nonpoint Source Control Programs for Several Southern States. In: Hook, D. D.; Lea, R., eds. Proceedings of the Symposium: The Forested Wetlands of the Southern United States.; 1988 Jul 12; Orlando, FL. Asheville, NC: USDA Forest Service; 1988; General Technical Report SE-50: 163-168.

Concerns about the impact of nonpoint source activities (including forest management operations) on water quality led to the development of state nonpoint source control programs. Most southern states have adopted nonpoint source control programs for forest operations based on state approved Best Management Practices (BMPs). Based on ongoing program assessments, those states which have promoted their nonpoint source control programs have been successful in protecting water quality. Of the program assessment methods utilized, qualitative surveys of BMP use and effectiveness and focused watershed studies have proven most useful. The success of BMP-based nonpoint source control programs provides an example for the future wetlands management control programs.

102. Ice, G. G.; Beschta, R. L.; Craig, R. S.; Sedell, J. R. Riparian Protection Rules for Oregon Forests. In: Proceedings of the California Riparian Systems Conference.; 1988 Sep 22; Davis, CA. : USDA Forest Service; 1989; General Technical Report PSW-110: 533-536.

Forest Practice Rules under the Oregon Forest Practices Act were modified in 1987 to increase protection of riparian areas adjacent to timber harvest operations. These modifications addressed concerns about water quality protection and retaining trees as sources of large woody debris for future stream channel structure. The rule changes triggered debate about the quantity and quality of trees that should be left in riparian zones. Issues still under discussion include the silvicultural consequences of these rule modifications, and the need to better predict the costs and benefits of the rule changes.

103. Ice, George G. Guidelines and approaches for forest riparian management: State forest practice rules. In: Proceedings 1989 national convention: forestry on the frontier; 1989 September 24-27; Spokane, Washington. Bethesda, Maryland: Society of American Foresters; 1990; Publ. 98-02: 94-98.

State agencies have recognized that forest riparian areas have special value for protecting water quality and fish habitat. Using available information, these agencies have crafted guidelines and forest practices rules designed to meet water quality goals. In recent years, forest practice rules have been reevaluated in light of new objectives for protecting stream habitat for fish and wildlife. States are now using adaptive management principles to develop information about the effectiveness of forest practices while implementing management programs. Management elements for riparian areas include: Classification, control of timber removal, road building and site preparation, and management for shade, recruitment of large woody debris, and snag retention.

104. Ice, George G. Industry research to address forest water quality information needs. In: Blosser, Russell O., Technical director. Industry Programs Dealing with Forestry Management Practices and Environmental Quality. New York, New York: National Council of the Paper Industry for Air and Stream Improvement; 1983 Jun; NCASI Technical Bulletin No. 402: 1-37. 37 Pages.

This paper will discuss the recent history of some water quality information needs faced by the forest industry and the types of research-information gathering approaches that have developed to address those needs. In particular, we will attempt to provide a perspective on the role of forest industry conducted or sponsored water quality research in the overall forest water quality effort.

105. Ice, George G. Landslide inventories, current research and pending forest practice act rule changes for mass wasting associated with forest management practices. In: Blosser, Russell O., Technical Editor. Forest Management Practices and Natural Events - Their Relation to Landslides and Water Quality Protection. New York, New York: National Council of the Paper Industry for Air and Stream Improvement; 1983 Jun(NCASI Technical Bulletin No. 401). 20 pages.

Landslides are a natural erosional process. However, inventories of landslides have shown that the rate of occurrence of landslides can be influenced by forest practices. Recently Oregon, Washington and California have been addressing new controls for mass wasting from forest lands (1-3). This paper will review emerging changes in the Oregon Forest Practice Rules and discuss how existing landslide inventories are helping to identify appropriate practices, questions being raised about management options, and current research which could provide answers to questions about landslides in managed forests.

106. Ice, George G. (NCASI). Programs Dealing with Forest Management and Water Quality. in: Research on the Effects of Mass Wasting of Forest Lands on Water Quality and the Impact of Sediment on Aquatic Organisms. New York, NY: NCASI; 1981 Apr; TB No. 344. 1-56.

For the past three years the Southern and West Coast Regional meetings have featured one or more sessions covering research and field investigations on the impact of forestry management practices on receiving water quality and utility. This technical bulletin is an assembly of the papers and abstracts of presentations made at the West Coast Regional Meeting in 1981 at sessions arranged by Dr. George G. Ice, Research Hydrologist at the West Coast Regional Center. The program featured four papers on the relationship of forestry management practices and mass movement of soils. James Sachet, Washington Department of Ecology; Robert R. Ziemer, USDA Forest Service, Dale McGreer, and James McNutt, Potlatch Corporation; and George G. Ice participated in this segment of the program. William L. Jackson and Robert L. Beschta, Oregon State University, presented a progress report on the forest products industry funded project underway at the University on the movement of sediment in stream systems. The subject of aquatic biology was covered by Dr. E. Salo, University of Washington, who described elements of an extensive program underway at the University of Washington on the impact of sediments from logging-associated activities on the fishery resource. Charles Hawkins, Oregon State University, described the relative effects of sediment and canopy removal on stream communities. Dr. George G. Ice presented a summary of ongoing research programs and information needs relating to forestry management practices and water quality in the Northwest.

107. Ice, George G. Research on the effects of mass wasting of forest lands on water quality and the impact of sediment on aquatic organisms. : National Council of the Paper Industry for Air and Stream Improvement; 1981; Technical Bulletin No. 344.

108. Idaho Department of Health and Welfare, Division of Environmental Quality. Southeastern Idaho forest practices water quality audit 1988. Boise, Idaho: Idaho Department of Health and Welfare, Division of Environmental Quality; 1989 May. 17 pages plus appendices.

109. Irland, L. C. Logging and Water Quality: State Regulation in New England. Journal of Soil and Water Conservation. 1985; 40(1): 98-102.

Timber harvesting and associated roadbuilding can affect water quality in New England. Because affected streams are important for water supply and fisheries and because the waters are state property, there is basis for public policy concern. The problem is real. Under federal and state laws, this general concern has resulted in efforts to regulate these impacts. Maine, Connecticut, Massachusetts, and Vermont employ contrasting strategies. Maine regulates logging and major haul roads by standards and permits in selected areas. Connecticut has no state program, but some towns are regulating logging. Massachusetts recently established a statewide, advance permit requirement for all operations above a minimum size. And Vermont has established an innovative cooperative program designed to mitigate sedimentation through cooperation with a loggers' organization. These programs labor under several difficulties: landowner and logger resistance; lack of adequate enforcement resources: and an inadequate base of technical knowledge about logging effects, fishery impacts of sedimentation, and the effectiveness of prescribed mitigating measures. Also, the regulatory programs deal not only with erosion but with aesthetics, wildlife habitat, or other values. The states have made only minimal staff commitments to education and enforcement of these laws. Regulatory authorities apparently place low priorities on logging practices, compared to other environmental concerns. In most cases, however, the Cooperative Extension Service and professional groups are providing significant staff support for the educational activities. At present there is no basis for saying which of these strategies is superior (17). Before additional efforts are made to address nonpoint pollution caused by logging, an unbiased, thorough field evaluation of the effectiveness of current programs is needed. Such a review should be undertaken by a reputable, impartial investigator or team not directly involved in regulatory programs or the forest products industry. While costly, it is essential to build a sound basis for determining if existing efforts need to be modified or if new initiatives are in order. Until then, a top priority should be additional field research on effective sediment control practices and their costs, on the impacts of sedimentation on fisheries, and on low-impact logging machinery and systems. Such research should build a basis for better ways to rate erosion risks and plan control measures, as have been developed in the West (33, 43, 44). Many people familiar with current programs believe they are warranted. The question is whether the programs are cost-effective and adequately meet needs.

110. James, B. R.; Bagley, B. B.; Gallagher, P. H. Riparian Zone Vegetation Effects on Nitrate Concentrations in Shallow Groundwater. In: Proceedings of the 1990 Chesapeake Bay Research Conference; Baltimore, MD. ; 1990.

Riparian zones have been suggested as components of shoreline ecosystems that will reduce nitrate concentrations in groundwater flowing to surface waters of the Chesapeake Bay and its tributaries. Little is known, however, about chemical and biological processes affecting nitrate at the soil-groundwater interface beneath riparian vegetation. Changes in nitrate concentrations in groundwater between an agricultural field planted to tall fescue (Wye Island, Oueen Anne's County, MD) and riparian zones vegetated by leguminous or non-leguminous trees were measured biweekly in transects of monitoring wells spaced five to ten meters apart. Replicated plots in the leguminous and non-leguminous sections were used to investigate effects of different vegetation management practices on groundwater chemical composition. Control plots (no cutting of native trees and understory vegetation) were compared with others in which only trees were cut or in which trees and understory plants were clear-cut and replaced with tall fescue. Average groundwater nitrate concentration was 3.4 mg N/L in control plots vegetated by non-leguminous trees, with a decrease from 4.1 in field wells to 2.4 mg N/L in riparian wells 10 m from the field margin. Average nitrate concentration was 5.8 mg N/L in plots in which trees had been cut, and smaller or no changes were measured from field wells to those closer to the shoreline. Nitrate concentration beneath leguminous (black locust) trees was 5.2 mg N/L, and cutting and preventing regrowth of these trees lowered nitrate concentration to 1.2 mg N/L. The attenuation of nitrate was greatest in a non-leguminous control plot during all seasons. The greatest decrease in nitrate concentration (93-96%) was measured in the fall and winter, and minimum attenuation occurred in summer. In cut-tree and clear-cut plots with similar water table depths, nitrate increased from field to riparian wells, with no clear seasonal patterns. The results have implications for management of shoreline ecosystems of the Chesapeake Bay to protect water quality, especially for control of nonpoint sources of nitrate pollution. They also are pertinent to understanding the role of trees and forest land in affecting water quality of the Bay.

111. Johnson, S. R.; Gary, H. L.; Ponce, S. L. Range Cattle Impacts on Stream Water Quality in Colorado Front Range. : USDA Forest Service; 1978; Research Note RM-359.

In the last 100 years, most of the meadows along the perennial streams in the Front Range of Colorado have been heavily used by cattle and other livestock. Undoubtedly, due to the large numbers of animals (some 300,000 head in 1950 (Gary 1975)), the quality of most streams has been impacted to some degree by livestock waste products. The measured physical and chemical properties of streamflow in this study indicated minor pollution from unknown upstream source. These findings, however, do not provide significant evidence of major long-term cumulative impairment of water quality due to past grazing practices in the area. The pasture comparisons provided some insight as to the immediate effects of grazing. At stocking rates of about 1.2 ha of usable pasture per cow plus calf pair, a rate locally common for short-term, seasonally grazed pastures, there were no statistically significant differences in the physical and chemical properties of the stream water that could be attributed to the grazing cattle. However, the cattle contributed significantly to the bacterial contamination of the stream, but after removing the cattle, bacterial counts dropped to levels similar to those in the ungrazed pasture within a short time. Today, range cattle (cows) number only about 122,000 head in the counties along the Front Range in Colorado or about 13% of the total number for the State. Thus, the regional potential of livestock wastes contaminating streams along the Front Range has also been greatly reduced from earlier years and permanent removal of the cattle from the productive live stream flood plains does not appear justified.

112. Johnston, Robert S. Effect of small aspen clearcuts on water yield and water quality. Ogden, Utah: USDA-Forest Service, Intermountain Forest and Range Experiment Station; 1984 Dec; Research Paper INT-333. 9 pages.

Removing deeply rooted aspen from 13 percent of a 217-acre (88-ha) watershed had no significant effect on the streamflow timing, peak flow, or annual streamflow yield. Similarly, there were no significant changes in streamflow chemistry attributed to cutting from the catchment or from the ephemeral streams draining the individual cutting units. The lack of measurable effects from harvest may be attributed to the small size of the area cut and the minimal disturbance during cutting. Also, some treatment effects may have been masked by the network of beaver dams in the catchment. The study does emphasize two important principles: (1) anticpated water yield increases should not be simply extrapolated to the area of harvest and (2) the extrapolation of precipitation measurements, particularly snow, to areal distribution and the subseqent calculation of water yield can lead to serious errors, especially in mountainous terrain.

113. King, John G. Validating water quality standards. In: Proceedings of the National Soil and Water Monitoring Workshop; 1989 March 13-16; Sacramento, California. Washington D. C.: USDA-Forest Service, Watershed and Air Management; 1989; Report WO-WSA-1: 139-145.

114. Klock, G. O. Modeling the Cumulative Effects of Forest Practices on Downstream Aquatic Ecosystems. Journal of Soil and Water Conservation. 1985; 40: 237-241.

Forest land managers are concerned about the potential cumulative effects of multiple management activities, over time and space, within a watershed on downstream aquatic ecosystems. To determine a watershed's hydrologic condition, a Watershed Cumulative Effects Analysis (KWCEA) model was developed. The model uses key watershed parameters affecting streamwater quality and quantity. Its index value implies relative, cumulative-effect, risk-rating levels for past, current, and future forest management practices as well as worst-case conditions. The model is paricularly useful for evaluating the potential downstream impact of all forest practice options within a watershed. Output from the KWCEA model can also be used to coordinate the schedule of forest practices among several land ownerships within a watershed.

115. Kochenderfer, J. N.; Aubertin, G. M. Effects of Management Practices on Water Quality and Quantity: Fernow Experimental Forest, West Virginia. In: Municipal Watershed Management Symposium Proceedings. : USDA Forest Service; 1975; General Technical Report NE-13: 14-24.

Results of 22 years of forest hydrology research on the Fernow Experimental Forest are reviewed. Forest influences were measured on quantity and timing of streamflow and on parameters of water quality such as turbidity, temperature, specific conductance, pH, alkalinity, and nutrient concentrations. These results indicate that it is currently not practical to manage forest land for both sustained increased water yield and merchantable timber products, and that forest land can be managed for a variety of uses without impairing water quality if these uses are regulated intelligently.

116. Krammes, J. S.; Willets, D. B. Effect of 2,4-D and 2,4,5-T on Water Quality After a Spraying Treatment. Pacific Southwest Forest and Range Experiment Station: USDA Forest Service; 1964; Research Note PSW-52. 4p.

Stream pollution has not resulted from removing and chemically spraying vegetation at the bottom of Monroe Canyon on the San Dimas Experimental Forest. The riparian zone and intermediate slopes were handsprayed several times with a mixture of 2, 4-D and 2, 4, 5-T herbicide. In another study, brush on side slopes was cut and sprayed. Soil samples taken the first month after treatment showed no traces of herbicides.

117. Kuenzler, E. J. Value of Forested Wetlands as Filters for Sediments and Nutrients. In: Hook, D. D.; Lea, R., eds. Proceedings of the Symposium: The Forested Wetlands of the Southern United States.; 1988 Jul 12; Orlando, FL. Southeastern Forest Experiment Station, Asheville, NC: USDA Forest Service; 1989; General Technical Report SE-50: 85-96.

The southern region has extensive freshwater forested wetlands. Those along streams can remove major percentages of suspended sediments from cropland runoff and of nitrogen and phosphorous from both point- and nonpoint-sources of pollution. Continuing losses of forested wetland area and function reduce sediment- and nutrient-removal capability with consequent adverse effects on water quality.

**118. Lackey, R. T. Forest Practices and Water Quality: Effects of Pollution on Aquatic Life. Workshop on Forest Practices and Water Quality.; Atlanta. : Virginia Polytechnic Institute, Blacksburg, VA; 1975. 9p.
Note: need.**

**119. Lai, F. S.; Norajiki, A. J. Some stream water quality characteristics of two small logged over watersheds in Selangor. Pertanika. 1988; 11(3).
Note: have it.**

A study of selected stream water quality parameters was carried out in two forested watersheds in the Air Hitam Forest Reserve with varying degrees of disturbance. The site had been a lowland dipterocarp forest before logging, which started in 1930 and continued on a commercial and subsistence basis until 1983. It is now designated a secondary disturbed forest. Logging had used a crawler tractor. The study period was 6 months (from Aug. 1983 to Jan. 1984) and involved regular sampling at between 1400 and 1500 h. The results indicated that all parameters observed in the relatively more disturbed watershed WA (where logging stopped in July 1983) were higher than in the less disturbed basin WB (where logging stopped a year earlier). Mean values of stream water quality parameters of WA and WB respectively were as follows: water temperature 25.3 and 25.2degC; dissolved oxygen 6.7 and 6.4 p.p.m.; pH 5.55 and 5.25; conductivity 16.0 and 11.3 micromhos/cm; suspended solids 22 and 7 mg/litre; and total dissolved solids 36 and 31 mg/litre. The findings suggest that logging operations had varying influences on the water quality parameters. Although affected, the water quality remains good, aided by environmental considerations during logging operations.

120. Lawson, E. R. Effects of Forest Practices on Water Quality in the Ozark Ouachita Highlands. In: Forestry and Water Quality: A Mid South Symposium. Little Rock, AR: 130-140.

Water yield and water quality information from studies conducted in the Ouachita Mountains, Ozark Plateaus, and Boston Mountains of Arkansas are summarized. Undisturbed areas in the Ozark Plateau averaged less than 20 lbs/acre/year (22.4 kg/ha) sediment losses. Maximum annual sediment yields of only 116.8 lbs/acre (130.9 kg/ha) were observed during the first year after clearcutting in the Ouachita Mountains. Within three years, the pretreatment sediment yields were back to normal levels on all treated watersheds. These studies show that sediment losses associated with several forest practices in the upland areas of Arkansas are very low.

121. Levno, A.; Rothacher, J. Increases in Maximum Stream Temperatures After Logging in Old-Growth Douglas-Fir Watersheds. Pacific Northwest Forest and Range Experiment Station: USDA Forest Service; 1967; Research Note PNW-65. 12p.

Water temperature, one of the important factors of water quality, is strongly influenced by solar radiation reaching the stream and its channel. To determine the water temperature changes that occur when old-growth Douglas-fir forests are logged, maximum and minimum thermometers were installed in three streams on the H. J. Andrews Experimental Forest near Blue River, and records were maintained from 1959 through 1966. The three small (237-, 150-, and 250-acre) northwest-sloping watersheds under study are located on the west side of the Cascade Range at an elevation of 1,500 to 3,500 feet (fig. 1). Climate is maritime with cool, dry summers and mild, wet winters. Average annual temperature is approximately 49 degrees F, with a January average of 35 degrees and a July average of 69 degrees F. Snow is usually short-lived at these elevations. Topography is steep, and vegetation is predominately dense old growth Douglas-fir with a relatively sparse understory. Each watershed contains about 10,000 feet of live stream with flow variations from 0.025 cubic foot per second during summer lows up to 60 cubic feet per second during winter storms.

122. Lisle, Thomas E.; Hilton, Sue. Respectively, Research Hydrologist and Hydrologic Technician, USDA Forest Service, Pacific Southwest Forest and Range Experiment Station. Water Resources Bulletin, American Water Resources Association. 1992 Apr; Vol. 28, No. 2: 371-383.

During waning flood flows in gravel-bed streams, fine-grained bedload sediment (sand and fine gravel) is commonly winnowed from zones of high shear stress, such as riffles, and deposited in pools, where it mantles an underlying coarse layer. As sediment load increases, more fine sediment becomes available to fill pools. The volume of fine sediment in pools can be measured by probing with a metal rod, and, when expressed as the fraction (V*) of scoured residual pool volume (residual pool volume with fine sediment removed), can be used as an index of the supply of mobile sediment in a stream channel. Mean values of V* were as high as 0.5 and correlated with qualitative evaluations of sediment supply in eight tributaries of the Trinity River, northwestern California. Fine-sediment volume correlated strongly with scoured pool volume in individual channels, but plots of V* versus pool volume and water surface slope revealed secondary variations in fines volume. In sediment-rich channels, V* correlated positively with scoured pool volume; in sediment-poor channels, V* correlated negatively with water-surface slope. Measuring fine sediment in pools can be a practical method to evaluate and monitor the supply of mobile sediment in gravel-bed streams and to detect and evaluate sediment inputs along a channel network.

123. Logan, B.; Clinch, B. Montana Forestry BMP's. : Montana Department of State Lands; 1991; Publication No. EB0096. 33p.

Montana's forest lands supply beauty, pure water, abundant wildlife, minerals, recreation, forage, timber and thousands of jobs. This book is dedicated to the stewardship of those qualities - especially pure water. It describes Best Management Practices (BMPs) for protecting water quality. If you work in the forest, own forest land, or are concerned about our forests, this publication is for you. It contains BMP guidelines and gives reasons for BMP's not just rules. However, reading these pages is not enough. Maintaining our forest's productivity and benefits can only be achieved by on-the-ground application of BMP's. How you apply BMP's in the forest will require practice and personal judgment. Two notations throughout these pages are intended to help. The "do not" symbol indicates practices you should avoid. The black blocks indicate official BMP's adopted by the State of Montana.

124. Lohrey, M. H. Stream Channel Stability Guidelines for Range Environmental Assessments and Allotment Management Plans. Pacific Northwest Region: USDA Forest Service; Unk. 23p.

The following guidelines have been developed as a relatively rapid technique to assess channel condition and water quality for project level planning. The specific objective of these procedures are to: 1) Provide a quantitative method to assess channel stability and projected water quality for project areas. 2) Provide an analysis procedure which gives a better resolution of channel/water quality objectives for specific project areas. 3) Provide a mechanism which facilitates prioritizing areas for other inventory procedures with different objectives (i.e. monitoring).

125. Lousiana Forestry Association. Recommended Forestry Best Management Practices for Louisiana. : Louisiana Department of Agriculture and Forestry; 1988. 18p.

The Federal Water Pollution Control Act Amendments of 1972, Public Law 92-500 (and as amended by Sec. 319, 1986), require the management of nonpoint sources of water pollution from sources including forest-related activities. Procedures called Forestry Best Management Practices (BMPs) have been developed to guide forest landowners, managers and timber harvesters toward voluntary compliance with this act. Maintenance of water quality to provide "fishable" and "swimmable" waters is central to this law's objectives. The Environmental Protection Agency (EPA) recognizes the use of BMP's as an acceptable method of reducing nonpoint source pollution.

126. Lowrance, R. R.; Todd, R. L.; Asmussen, L. E. Nutrient Cycling in an Agricultural Watershed: I. Phreatic Movement. Journal of Environmental Quality. 1984; 13: 22-27.

Much of the runoff from agricultural fields in the southeastern Coastal Plain is carried to a stream channel system in a shallow phreatic aquifer. This subsurface runoff often passes through a band of riparian forest before becoming streamflow. It is hypothesized that the riparian ecosystem acts as a nutrient sink and reduces the concentrations and loads of nutrients in the shallow aquifer before the nutrients reach the stream channel. Concentrations and loads (kg/m2) of NO3-N, NH4-N, organic N, dissolved molybdate-reactive P, total P, Ca, Mg, K, Cl, and SO4-S were measured in shallow phreatic wells at 37 locations on an agricultural watershed near Tifton, GA. Total water volume moving off the watershed in subsurface flow was < 1% of streamflow with corresponding small amounts of nutrients. Nitrate-N, Ca, and Mg had significantly higher concentrations in field wells than in forest or streamside wells. Concentrations of Cl were not reduced as water moved from field to forest. Processes within the riparian zone apparently converted primarily inorganic N from fields (76% NO3-N, 6% NH4-N, 18% organic N) into primarily organic N in streamside wells (10% N)3-N, 14% NH4-N, and 76% organic N). Concentration differences between field and forest wells indicated the riparian forest's ability to act as a sink for NO3-N, Ca, Mg, K, and SO4-S. Due to their role as nutrient sinks, riparian forests are important in maintaining stream water quality on agricultural watersheds.

127. Lynch, J. A.; Corbett, E. S. Effectiveness of BMP's in Controlling Nonpoint Pollution From Silvicultural Operations. In: Woessner, W. W.; Potts, D. F., eds. Proceedings of the Symposium on Headwaters Hydrology. Bethesda, MD: American Water Resources Association; 1989: 149-157.

Ten years of streamflow and water quality data were evaluated to determine the effectiveness of Best Management Practices (BMP's) in controlling nonpoint source pollution from an 110-acre commercial clearcut located in the Ridge and Valley Province of central Pennsylvania. The analyses addressed both short- and long-term changes in the physical and chemical properties and the hydrologic regime of the stream draining this 257-acre watershed. Overall, the BMP's employed on this commercial clearcut were very effective in preventing serious deterioration of stream quality as a result of forest harvesting. Although significant increases in nitrate and potassium concentrations and temperature and turbidity levels were measured, the increases were relatively small and, with the exception of turbidity, within drinking water standards. Increased turbidity levels were the result of wind thrown trees adjacent to the channel and were not directly related to timber harvesting activities. Nitrate and potassium concentrations and turbidity levels remained above pre-harvesting levels for as long as eight years following harvesting. Clearcutting also significantly increased water yield which in turn lowered the concentrations of some ions because of dilution. Increased water yields returned to pre-harvesting levels within four years as a result of rapid regrowth. The export of some ions increased; however, the increased export appeared to be insufficient to affect site productivity.

128. Lynch, J. A.; Sopper, W. E.; Corbett, E. S.; Aurand, D. W. Effects of Management Practices on Water Quality and Quantity: The Penn State Experimental Watersheds. In: Municipal Watershed Management Symposium Proceedings. : USDA Forest Service; 1975; General Technical Report NE-13: 32-46.

129. Lyons, J. Using the Index of Biotic Integrity (IBI) to Measure Environmental Quality in Warmwater Streams of Wisconsin. North Central Forest Experiment Station: USDA Forest Service; 1992; General Technical Report NC-149. 51p.

The IBI was originally developed by Dr. James Karr during the late 1970's and early 1980's to assess biotic integrity and environmental quality in small streams in Indiana and Illinois (Karr 1981, Karr et al. 1986). Karr and Dudley (1981) defined biotic integrity as "a balanced, integrated, adaptive community or organisms having a species composition, diversity, and functional organization comparable to that of natural habitat of the region." Although the specific attributes and expectations of the original version of the IBI apply only to Indiana and Illinois, the general principles underlying the IBI concept apply to many streams throughout North America. Karr recognized this, and he and his colleagues at the University of Illinois developed procedures for adapting the IBI for use in different regions (Fausch et al. 1984, Karr et al. 1986). Biologists and managers in other States and Canadian provinces have since modified the IBI to fit the physical and biological characteristics of streams in their areas. They have generally found the IBI to be a useful assessment and evaluation tool (Miller et al. 1988, Fausch et al. 1990). One of the most thorough modifications of the IBI has been done by the Division of Water Quality Monitoring and Assessment of the Ohio Environmental Protection Agency (Ohio EPA 1988). The Ohio EPA developed several versions of the IBI based on hundreds of fish community, habitat, and water quality samples from a wide variety of Ohio streams and rivers. The Ohio EPA uses the IBI extensively, and IBI scores have been incorporated into Ohio water quality standards. The Wisconsin version of the IBI that I present here is largely derived from the Ohio EPA "wading sites" version.

130. MacDonald, L. H. Sediment Monitoring: Reality and Hope. Dept. of Earth Resources, Colorado state University. 8 pages plus figures.; Fort Collins, CO.

Regulation of water quality in the U.S. is largely based on the maintenance and enhancement of the designated beneficial uses of water. The overall goals of the Clean Water Act and its amendments are couched in terms such as swimmable, fishable, and the propagation of aquatic life. The policies and mechanisms to achieve these goals--water quality standards, Best Management Practices (BMPs), antidegradation, total maximum daily loads (TMDLs)--all relate back to this concept of designated beneficial uses (EPA, 1988), and are all dependent on monitoring for their effective implementation (MacDonald et al., 1991). In most of the Western U. S. and Canada, coldwater fisheries are regarded as the designated use most sensitive to forest management activities. Public concern over the effects of forestry on streams and fish has triggered a series of intensive research projects to evaluate forestry-fisheries interactions (e.g., the Alsea study in Oregon, Carnation Creek in British Columbia) (Moring, 1975; Chamberlin, 1988). These and other studies have not stilled what is often a highly-charged and emotional debate, with technical arguments sometimes serving as a smokescreen for other, unspoken objectives. From a scientific point of view, confirmation of the effects of forestry on aquatic ecosystems requires: (1) documentation of a change in the physical habitat (temperature, turbidity, bed material particle size, amount of cover, pool depth, etc.), and (2) a link between these changes in physical habitat to the designated use of concern (e.g., coldwater fish populations, "biological integrity"). In the last five years several publicaions have reviewed different aspects of these interactioins between land management activities and aquatic ecosystems (Salo and Cundy, 1987; Chapman and McLeod, 1987; MacDonald et a., 1991; Reid, 1992). At this point there seems to be little point in generating another broad "state of knowledge report" on forestry-fishery interactions, at least for the Pacific Northwest.

131. MacDonald, L. H.; Smart, A. W.; Wissmar, R. C. Monitoring Guidelines to Evaluate Effects of Forestry Activities on Streams in the Pacific Northwest and Alaska. University of Washington, Seattle, WA.: USEPA Region 10 in Cooperation with the Center for Streamside Studies; 1991; EPA/910/9-91-001. 166p.

This document provides guidance for designing water quality monitoring projects and selecting monitoring parameters. Although the focus is on forest management and streams in the Pacific Northwest and Alaska, a broader perspective is taken, and much of the information is more widely applicable. Part I reviews the regulatory mechanisms for nonpoint source pollution and defines seven types of monitoring. A step-by-step process for developing monitoring projects is presented. Because monitoring is a sampling procedure, study design and statistical analysis are explicitly addressed. The selection of monitoring parameters is defined as a function of the designated uses, management activities, sampling frequency, monitoring costs, access, and the physical environment. Approximately 30 parameters are rated with regard to these controlling factors. A qualitative combination of these rankings yields recommended monitoring parameters for various management activities. This parameter selection process has been incorporated into an interactive PC-based expert system called PASSSFA. Part II is a technical review of the parameters, which are grouped into six categories: physical and chemical constituents, flow, sediment, channel characteristics, riparian, and aquatic organisms. The review of each parameter is organized into seven sub-sections: definition, relation to designated uses, response to management activities, measurement concepts, standards, current uses, and assessment.

132. Martin, C. W.; Noel, D. S.; Federer, C. A. Effects of Forest Clearcutting in New England on Stream Chemistry. Journal of Environmental Quality. 1984; 13(2): 204-210.

Differences in stream chemistry between recently clearcut and nearby uncut watersheds were generally small in a wide variety of soil and forest types throughout New England. Water samples were collected during six periods of the year in 1978 and 1979 from 6 entirely clearcut, 32 partially clearcut, and 18 uncut watersheds. The largest differences that could be attributed to harvesting occurred in entirely clearcut watersheds, especially in the White Mountains of New Hampshire. In one area of the White Mountains, inorganic N was 4 times higher (2 mg/l), and Ca was 2 times higher (4 mg/l) in streams from a clearcut watershed than in a nearby uncut watershed. Elsewhere, only minor changes in stream chemistry resulted from cutting; the amount of the cutting response was of the same magnitude as natural variations among streams draining similar watersheds. Clearcutting less than entire watersheds, patch and strip cuts, and buffer strips along streams all appear to reduce the magnitude of changes in stream chemistry.

133. Mason, Donald Proctor (Plymouth State College). Physical and Hydrochemical Effects on Stream Insect Communities in the White Mountain National Forest of New Hampshire. Thesis. Plymouth State College; 1982 Sep.

Substrate composition appeared to have the most influence on insect community composition of streams in the New Hampshire White Mountain National Forest. Coarse substrata provided niches for colonization by a diverse and abundant fauna. Substrates dominated by rubble had larger communities than those dominated by boulders and sand because rubble had more inhabitable surface area than boulders, yet was more stable than sand. Many insects in this study are ubiquitous, though abundance at particular sites was determined by the streambed composition as well as other environmental factors. Hydrochemistry was shown to be correlated with size and diversity of the communities and its possible indirect effects through interactions with substrate composition and other physical factors requires further research. The composition of food resources also appears to inlfuence stream faunal communities. This factor appears to be more important in determining qualitative rather than quantitative aspects of the community. To obtain a more complete understanding of rheophile communities in the White Mountains, additional research is recommended. Taxonomic studies are essential to determine exactly what species are present in this area. Descriptions of ecological communities at the generic or family level are not adequate for comprehensive analyses of the steam ecosystem since many species may be involved, each with different ecological preferences. Effects of chemical ions could also be more completely understood by comparing different streams with identical substrata and canopy cover. Measurements of ion fluctuations should be included in these studies, since insects emerging during periods of high or low ion concentration may not be affected by these high or low levels, though ovipositing females may avoid these habitats. Comprehensive understanding of stream ecosystems could promote the development of predictive models and describe the impact of environmental alteration on these systems. This knowledge would be extremely valuable in assessing water quality for future human needs.

134. Matida, Y.; Furuta, Y.; Kumada, H.; Tanaka, H.; Yokote, M.; Kimura, S. Effects of some herbicides applied in the forest to the freshwater fishes and other aquatic organisms - 1. Survey on the effects of aerially applied sodium chlorate and a mixture of 2,4-D and 2,4,5-T on the stream community. Bulletin of the Freshwater Fish Research Laboratory, Tokyo. 1975; 25(1): 41-53.

No significant toxic effects were observed in the stream communities of 2 mountain areas following aerial treatment with Kusa-tohru (sodium chlorate 50%) at 200 kg product/ha and Brush-Killer (2,4-D + 2,4,5-T) at 150 kg [product ?]/ha, respectively. Water quality data are included.

135. Maxted, J. R. Water Quality Standards and Monitoring for NPS Activities in Wetlands. In: Hook, D. D.; Lea, R., eds. Proceedings of the Symposium: The Forested Wetlands of the Southern United States.; 1988 Jul 12; Orlando, FL. Southeastern Forest Experiment Station, Asheville, NC: USDA Forest Service; 1989; General Technical Report SE-50: 146-148.

Water quality standards (WQS), and in particular numeric and narrative criteria, were designed to control particular chemical contaminants in point source discharges. Guidance came from EPA in the form of national criteria recommendations. The water quality impacts from nonpoint source (NPS) activities, including silviculture practices in wetlands, are not adequately addressed by the existing criteria developed by EPA and contained in State water quality standards. Criteria for NPSs need to be developed and will likely be substantially different from chemical criteria. Criteria based on the resident biota (i.e. biocriteria) have been developed by a few states for streams and rivers and show promise for wetlands. These biocriteria must be developed on a regional, rather than national, basis. Therefore the development of meaningful and effective criteria to address NPS activities must involve individuals and groups outside EPA.

136. Maxwell, J. R. Effects of Prescribed Fire on Soil and Water in Southern National Forests. In: Final Environmental Impact Statement: Vegetation Management in the Coastal Plain/Piedmont, Volume II, Appendix B. Atlanta, GA: USDA Forest Service; 1988; Management Bulletin R8-MFB-23. 34p.

Effects of prescribed fire on soil and water vary with type of burn. Slash burns can reduce soil quality if the burn is severe, consuming all litter and duff and altering mineral soil on much of the area. Major effects are loss of soil biota, structure, organic matter, and nitrogen. Severe burns also yield high sediment loads in rugged terrain. On poor soils, moderate burns may prevent buildup of organic matter and nitrogen vital to site recovery. Underburns more often than every 3 years can reduce soil quality via the loss of soil organisms and organic matter. On poor soils, burns more often than every 5 years may prevent buildup of organic matter vital to site recovery. Unless alternated with winter burns, summer burns can cause excessive nitrogen loss. Underburns can enhance soil quality by retarding soil weathering. Grassland burns cause few impacts if done less often than ever 2-3 years.

137. McClimans, Richard J.; Taylor, George F. ,. II; Huggins, Andrew; Bowen, Ann F. Annotated bibliography of forest practices in relation to water quality (with special reference to Section 208 of the Federal Water Pollution Control Act amendments of 1972). ; 1978 Jan; AFRI Research Report No. 37.

138. McClurkin, D. C.; Duffy, P. D.; Nelson, N. S. Changes in Forest Floor and Water Quality Following Thinning and Clearcutting of 20 Year Old Pine. Journal of Environmental Quality. 1987; 16(3): 237-241.

Effects of timber cutting on forest floor, sediment movement, and chemical quality of percolating water and of plot runoff are reported for pole-size loblolly pine (Pinus taeda) plantations on fragile soils of the upper Coastal Plain. Treatments were clearcut, thin, and no cut. Water quality measurements were derived for runoff samples from 0.002-ha plots and for percolating water from zero-tension lysimeters at a 15-cm depth. Forest floor on clearcut plots was reduced to near the minimum regarded as necessary for site protection within two years. Regardless of cutting treatment, more N and P were coming into the plots via precipitation than were leaving via plot runoff and percolation combined. More K appeared to be leaving the sites than was coming in via rainfall, regardless of the cutting treatment. Sediment concentrations in plot runoff tended to be proportional to cutting intensity. Nutrient content in percolation waters was unrelated to cutting intensity. Nutrient concentrations in plot runoff were high compared to concentrations reported in stormflows from local, small catchments with similar characteristics, but plot runoff was < 3% of annual rainfall.

139. McColl, J. G.; Grigal, D. F. Nutrient Losses in Leaching and Erosion by Intensive Forest Harvesting. In: Proceedings Impact of Intensive Harvesting on Forest Nutrient Cycling. College of Environmental Science and Forestry: State University of New York; 1979: 231-248.

Deep leaching and erosion are both pathways of nutrient loss from sites following intensive harvesting. Temporary increases in leaching losses may degrade surface water quality, but generally will not be great enough to measurably decrease site quality under well managed harvest and post-harvest conditions. Amounts of nutrients lost in erosion can be very great, especially from associated road construction. Mechanisms of leaching are understood, and leaching rates are relatively easily measured and may even be predictable in some cases. In contrast, erosional losses are difficult to measure, and often difficult to predict or control. Good engineering in both road placement and harvesting method can greatly minimize losses. Future work should concentrate on combined watershed/small-plot studies over a wide range of site conditions, with realistic treatments. More attention should be given to soil properties, microbiological processes, and atmospheric inputs, and their interactions with intensive harvesting, especially "whole-tree" techniques. Emphasis in assessing the importance of leaching and erosion should be directed at determining loss of productivity, and not simply the amount of nutrient movement.

140. McDonald, Glen A. (USDA Forest Service, Pacific NW Region). Methods for Testing Effectiveness of Washington Forest Practices Rules and Regulations with Regard to Sediment Production and Transport to Streams. Edmonds, Washington: Pentec Environmental, Inc.; 1991 Jun 28; TFW-WQ8-91-008. 1-124.

The purpose of this project is to develop a methodology to test how effectively the Washington Forest Practice Rules and Regulations (Washington State Forest Practice Board, 1988) minimize sediment production and delivery of sediment to streams. Washington statue 173-202 WAC identifies specific forest practice regulations as Best Management Practices (BMPs), which are required to protect water quality from impacts caused by forest management activites. The Washington Department of Ecology (WDOE) is required by State and federal statue to assess how effectively the BMPs maintain water quality. The methodology of testing the forest practice rules' effectiveness developed in this report is based on a multidisciplinary approach ranging from geomorphology to forestry. The method is based on several supporting tasks including a literature review of the sources and severity of sediment production in managed forests, the geographical variation of erosion processes and magnitudes across Washington State, and an analysis of the conceptual or theoretical effectiveness of the forest practice rules at preventing erosion. The approach taken in this report is to design a method to evaluate the effectiveness of forest practice rules (Best Management Practices) in minimizing specific erosion processes. Therefore, the emphasis is on detecting individual erosion processes in managed forested landscapes; describing their general nature, rate, timing, and persistence; and assessing the BMP measures used to mitigate them. Placing the emphasis on individual erosion processes in this way makes possible the design of a flexible field method to evaluate the effectiveness of specific forest practice rules or sets of rules that influence each process. Measurement methods differ according to erosion process, as do the appropriate time and space scales over which measurements must be conducted. For example, numerous studies have documented that landslides related to timber harvest typically occur several years following cutting. Thus, a method designed to detect this sediment source would involve a combination of field and ground surveys conducted several years after forest practice. On the other hand, surface erosion from roads is most intense during the time in which a road is used most intensively and so a field-based method would be most appropriate during the time of intensive use. The proposed methodology emphasizes the production of sediment from individual erosion processes and the routing of that sediment to stream channels. General statements can be made about the amount, timing, grain size, downstream transport, and persistence of sediment in channels, but sediment transport and storage in channels is not addressed directly within this report. The method makes use of the general framework and specific tools of the sediment in a drainage basin (for general review, see Dietrich et al., 1982), but the method is restricted to a partial sediment budget emphasizing production only, such as that used by Reid et al. (1981).

141. McGreer, Dale J. Assessing the effectiveness of the Idaho Forest Practices Act. In: Industry, State, and Federal Programs designed to assess and protect water quality associated with managed western forests. New

York, New York: National Council of the Paper Industry for Air and Stream Improvement; 1985 Jul(NCASI Technical Bulletin No. 466): 45-49.

This paper summarizes recent experiences with Idaho's Forest Practices Act and water quality standards. For the same reasons that the discussion by Arnie Skaugset of the California Act is valuable, so is a discussion of the Idaho Forest Practices Act: The actions of any one of the western states significantly affects EPA and state policy and direction.

142. McGreer, Dale J. A study of erosion from skid trails in northern Idaho. In: Measuring and assessing the effectiveness of alternative forest management practices on water quality. New York, New York: National Council of the Paper Industry for Air and Stream Improvement; 1981 Aug; NCASI Technical Bulletin No. 353.

For the past three years the Southern and West Coast Regional meetings have featured one or more sessions covering research and field investigations on the impact of forestry management practices on receiving water quality and utility. This technical bulletin is an assembly of the papers and abstracts of presentations made at the West Coast Regional Meeting in 1981 at a session arranged by Dr. George G. Ice, Research Hydrologist at the West Coast Regional Center. The program featured three papers on sediment generation, its measurement, and its routing through the receiving water system. Dale J. McGreer, Potlatch Corporation, George G. Ice, NCASI, and Robert L. Beschta, Oregon State University participated in this segment of the program. The interrelationships of forest management practices and the aquatic community were dealt with in four papers. Fred H. Everest and William R. Meehan, USDA Forest Service, described some effects of the debris torrents on the habitat of anadromous salmonids. Carl E. Samuelson, ITT Rayonier, Inc. summarized a long term study of the impact of logging and the fish habitat in five stream systems. Peter A. Bisson, Weyerhaeuser Co., described the classification system developed within the company for assessment of specific forestry practice impacts on second to fifth order streams in Western Washington. Timothy J. Hall and George G. Ice, NCASI, identified information gaps that exist in relating the impact of forest management practices, sediment load generated, and its effect on aquatic organisms. Finally, Logan A. Norris, USDA Forest Service, outlined the importance of the use of chemicals in modern forest management practices. He emphasized the possibilities for minimizing the entry of forest chemicals into receiving waters through proper application practices and pointed out that the magnitude and duration of exposure of aquatic organisms and/or users of the surface waters are largely determined by the pattern of chemical use.

143. McKnight, J. S. Water Quality Planning in Total Forestry as it Related to Section 208 of P. L. 92-500. Proceedings: "208" Symposium, Non-point Sources of Pollution from Forested Land; 1977 Oct 19; Carbondale, Illinois. Southern Illinois University: 257-266.

Assessment of the effect of forest practices on water quality for specific site conditions is an integral part of 208 planning. Specific impacts that will be felt by foresters include identification of critical sites, zoning streamside management, improving road construction and maintenance, selecting the right regeneration and harvesting methods, and greater concern with conversion of forest land to other uses. Training, education, forestry refinement, adoption of incentives, expanded research, and coordination with other plans to improve water quality will be some general results of the 208 planning process.

144. Meehan, W. R. Introduction and Overview. Chapter 1 in: Meehan, W. R., ed. Influences of Forest and Rangeland Management on Salmonid Fishes and Their Habitats. ; 1991; American Fisheries Society Special Publication 19: 1-15.

An awareness that management activities in forest and range lands can affect the productivity of salmonid habitats has increased during the last 30 years. Before then, timber harvest and processing, road construction, livestock grazing, mining, and other commercial and recreational activities on both public and private lands took place without much concern about their consequences for other resources, in particular for fish habitats. As this awareness developed, resource scientists and managers accelerated their efforts to understand the often complex relations between land-use activities and aquatic resources. In recent years, forest and range managers have come under increasing pressure to assure that fish habitats on public lands remain productive and that fish populations are maintained at levels that meet commercial, recreational, and subsistence demands. These are not easy tasks. Political pressures from various interest groups often put the manager "between a rock and a hard spot." Multiple-use management is often thought to mean that all resources on a piece of land are managed so that all the users of these resources obtain their desired products. In reality, all the resources may be considered, but not necessarily equally. Constraints will be applied in some fashion, either to manage for maximum production of one resource to the exclusion of some or all of the others, or to manage all resources so that everybody gets something, but nobody gets everything he or she would like. All the timber in a watershed, for example, cannot be cut down without seriously affecting water quality and hence fish production. Fishery managers will not accept this, and campers and backpackers will complain bitterly about the aesthetic degradation of the landscape. Maintaining all productive lands in a pristine condition is likewise not a viable option; our society demands products of land to maintain its standard of living. So we must strike some kind of compromise that allows us to obtain natural commodities without reducing the productivity of the land. Land, in this context, includes the water and aquatic resources associated with it. Much knowledge, though incomplete, exists to help resource managers plan for the protection and enhancement of salmonid habitats, but it is widely scattered throughout the scientific literature and the files of resource agencies. To be of use to managers and researchers, this information must be summarized and assembled into a source document that is readily available, understandable, and usable. As a start, the Pacific Northwest Research Station of the U.S. Forest Service published a series of reports between 1979 and 1985 entitled "Influence of Forest and Rangeland Management on Anadromous Fish Habitat in Western North America." The 14 reports summarized the information then available on the relation between forest and range management activities and anadromous fish habitats. The primary audiences for those publications were forest managers and fishery biologists. The series was well received and used extensively by managers, researchers, and other persons interested in the conservation and management of natural resources on public and private lands. The evident interest in this type of documentation led to a decision by the U.S. Forest Service and the American Fisheries Society to revise, update, and expand the information in the original reports. This book is the result. We have added chapters that describe stream ecosystems and how they relate to salmonid habitats, life histories and distributions of salmonids throughout North America, responses of fish populations to the changes brought about by land-management activities, planning strategies used to integrate fish habitats into natural resource management, and general approaches to managing salmonid habitats. The chapters corresponding to the original series have been extensively revised and updated. The tremendous amount of new information that has become available in this area during the last few years has been incorporated. The extensive reference section alone should be an invaluable compilation. In addition to managers and researchers, we hope the book will become a primary reference for students in fisheries, forestry, and other natural resource disciplines. Although the book still emphasizes anadromous fish and their freshwater habitats in western North America, we have included information on resident salmonids and have attempted to expand the applicability of the discussions to other regions of North America. Much of the information that focuses directly on western conditions applies to anadromous salmonids in the Atlantic and Great Lakes states and provinces, as well as to resident trout and char populations throughout North America. Likewise, much of the information describing the effects of forest management on fish habitats is relevant to habitat changes caused by road construction, mining, or some other activity. This book is certainly not the last word on the interrelations between salmonid production and the management of forest and range lands. Many of the problems facing resource managers have not been solved, and some probably have not even been identified. But we cannot place a moratorium on the harvest and use of natural resources while we learn precisely how all components of the environment will respond. We must manage our lands using our current knowledge while we continue to identify and explore better ways to accomplish this task and still protect, and where possible enhance, our valuable fishery resources. I hope this book will expedite our progress.

145. Meehan, W. R.; Farr, W. A.; Bishop, D. M.; Patric, J. H. Some Effects of Clearcutting on Salmon Habitat of Two Southeast Alaska Streams. : USDA Forest Service; 1969; Research Paper PNW-82. 45p.

A primary concern of land resource managers in southeast Alaska is the effect of timber harvesting on the fresh water environment of salmon. Salmon and timber are the two most important renewable resources in this region; they occur together - most of the watersheds that contain salmon streams also support commercial timber that will be harvested. Spawning by adult salmon, as well as egg and fry survival, may be influenced by timber harvest which may change the quantity, regimen, and quality of streamflow or impair adult migration by obstacles originating on logged watersheds. The economic importance of timber and associated forest resources, such as a recreation and wildlife, is increasing with the expanding woodpulp market, improving access, growing population, and expanding tourism. The amount of timber harvested has about doubled in the last 10 years; the present rate is expected to nearly triple by the end of the next 10 years. One aim of land management is to conduct this harvest in a manner that is compatible with salmon production. Before the pulpmill at Ketchikan was completed in 1954, most logging had been concentrated in the better stands along beaches and nearby valley bottoms. Subsequently, large-scale logging expanded inland to valleys and adjacent slopes, beginning near Hollis on Prince of Wales Island. This harvest provided an opportunity to study logging effects on the physical characteristics of salmon spawning streams. James (1956) has described the Hollis study area in considerable detail and discussed preliminary results obtained by the Alaska Forest Research Center (now the Institute of Northern Forestry). Since 1955, research has continued cooperatively with the U.S. Fish and Wildlife Service, Fisheries Research Institute of the University of Washington, and the Alaska Department of Fish and Game. The original objective of this study, which began in 1949, was to determine if clearcutting and high-lead yarding affected salmon migration and spawning. As the study progressed, the environmental requirements of salmon in fresh water and the effect of clearcutting on watershed factors became better understood. Consequently, the objective gradually changed to the determination of the effect of clearcutting on the physical factors of salmon spawning streams. This report summarizes the research and describes the main conclusions regarding the effect of clearcutting on streamflow, suspended sediment, water temperature, and log debris.

146. Meehan, W. R.; Lotspeich, F. B.; Mueller, E. W. Effects of Forest Fertilization on Two Southeast Alaska Streams. Journal of Environmental Quality. 1975; 4(1): 50-55.

Four streams in southeast Alaska were studied to determine the effects of forest fertilization with urea on basic productivity and water quality. An initial, short-term increase in ammonia-nitrogen was observed in the treated streams, and nitrate-nitrogen levels increased and remained high compared to control stream levels during the year following treatment. Concentrations did not approach those considered toxic to aquatic life or unsafe for human consumption. Changes in biomass of periphyton and benthic fauna as a result of fertilization were not detected.

147. Megahan, W. F. (Evaluating Effects of Land Use on Sedimentation - A Case for Sediment Budgeting). Hydrological Science and Technology: Short Papers. US Forest Service, Intermountain Research Station, Boise, ID: American Institute of Hydrology; 1985 Sep; Volume 1, Number 1, Pp. 13-16.

Understanding the linkages between erosion and sedimentation could help meet present needs for water quality monitoring and evaluatioin of environmental impacts. Development of sediment budgets to account for watershed erosion processes and zones of sediment storage is an approach to provide this understanding. A sediment budget for forested watersheds in the mountainous zone of the interior Western United States is presented along with data to quantify selected budget components. With modification, the sediment budget approach is applicable to watersheds anywhere regardless of size.

148. Megahan, Walter F. Effects of Forest Roads on Watershed Function in Mountainous Areas. Balasubramaniam, A. S. Proceedings of the Symposium on Environmental Geotechnics and Problematic Soils and Rocks; 1985 Dec; Bangkok, Thailand. ; c1987: 335-348.

Numerous examples from mountainous areas in the interior Western United States are used to illustrate the effects of forest road construction on watershed functions. Impacts can occur at onsite and downstream locations. Onsite effects include reduced forest productivity, increased runoff, and accelerated surface and mass erosion. Downstream, roads can change streamflow rates, water quality and channel characteristics. Accelerated erosion and resulting sedimentation are the most common and serious kinds of watershed damages caused by road construction. Basic principles for reducing road erosion and sedimentation impacts are presented.

149. Michael, Jerry L.; Neary, Daniel G. (USDA Forest Service, Auburn University; USDA Forest Service, University of Florida). Herbicide Dissipation Studies in Southern Forest Ecosystems. Presented at the Symposium on Pesticides in Forest Management, 11th Annual Meeting of the Sociiety of Environmental Toxicology and Chemistry; 1990 Nov 11; Arlington, VA. : Pergamon Press Ltd.; Environmental Toxicology and Chemistry, Vol. 12: 405-410.

Results of research on the movement of hexazinone, imazapyr, picloram, and sulfometuron in first-order watersheds in the Southern United States are presented. Herbicides contaminate surface waters to varying degrees, depending on application rate, method of application, product formulation, and site-specific characteristics. Highest concentrations are observed in streams in ephemeral pulses during the first three storm events after application. Streamside management zones greatly reduce the amount of herbicide entering streams from forestry applications. Soil persistence of herbicides is highly variable and a function of many site characteristics. Plant residues have been monitored and found to dissipate rapidly, with half-lives <40 d.

150. Mikalsen, K. T. Preliminary Results of Georgia Nonpoint Source Impact Assessment Study: Commercial Forestry. In: Research on the Effects of Forest Harvesting, Drainage, Mechanical Site Preparation, and Prescribed Fire on Water Quality. : National Council of the Paper Industry for Air and Stream Improvement; 1984; NCASI Technical Bulletin No. 442: 1-15.

The objectives of this three year project were to: (a) determine the quality of undisturbed (control) streams and waters affected by various nonpoint sources of water pollution, (b) identify water quality changes associated with land activities, and (c) determine whether those changes impaired or inhibited beneficial use of waters.

151. Miller, E. L.; Beasley, R. S.; Covert, J. Forest Road Sediments: Production and Delivery to Streams. In: Proceedings of Forestry and Water Quality: A Mid-South Symposium.; Little Rock, AR. ; 1985: 164-176.

The Arkansas statewide nonpoint source assessment estimated forest road erosion in the Alum Creek Watershed to average 692 T/mi/yr. A field study was initiated to measure sediment yields from instrumented road segments and project basin wide road sediment production and road sediment delivery to streams in the Alum Creek Watershed. Field evaluation of the road system, drainage structures, and sediment delivery capabilities of structures were used with sediment loss measurements to make the projections. A December rainstorm which exceeded the 100 yr 24 hr event and the wettest October on record highlighted the measurement period and significantly increased road erosion rates. Erosion rates from the instrumented road segments averaged 60 T/mi/yr and basin wide road erosion averaged 72 T/mi/yr. Sediment delivery from roads to streams was projected to be 7.9 T/mi/yr or about 1% of the assessment estimate.

152. Miller, E. L.; Beasley, R. S.; Lawson, E. Forest Harvest and Site Preparation Effects on Stormflow and Peakflow of Ephemeral Streams in the Ouachita Mountains. Journal of Environmental Quality. 1988; 17(2): 212-218.

Stormflow and peakflow response to three silvicultural treatments - clearcutting, selection cutting, and no disturbance (control) - were compared in a replicated small watershed study in the Ouchita Mountains of Arkansas. Watersheds were blocked according to aspect, location, soils, and geology in a randomized complete block design to test effects of treatments. Soils on the watersheds are shallow and were derived from sandstones and shale parent materials. Annual precipitation totals ranged from 72 to 142% of the long-term average (131.7 cm) during the study and a single rainstorm exceeding the 100-yr, 24-h event occurred the second year following harvest treatments. Overall, stormflow water yields did not increase significantly due to forest harvest treatments apparently because permeable soils and subsurface geology allowed deep seepage at the expense of stormflow. However, a treatment response was observed within one block and there was clearly a difference in stormflow response between blocks of watersheds. Annual stormflow as a percentatge of precipitation ranged from 2 to 59% across watersheds and years. Overall peakflows did not increase significantly due to treatment, but a treatment response was observed within one block of watersheds and there was a significant difference in peakflows between blocks. Treatment differences in stormflow and peakflow for the 100-yr event were not significant. Stormflow to precipitation ratios for this event ranged from 0.63 to 0.81.

153. Miller, E. L.; Beasley, R. S.; Lawson, E. Stormflow, Sedimentation, and Water Quality Responses Following Silvicultural Treatments in the Ouachita Mountains. In: Proceedings of Forestry and Water Quality: A Mid-South Symposium. Little Rock, AR; 1985: 117-129.

Watershed studies were conducted in the Ouachita Mountains of Oklahoma and Arkansas to test the effects of forest harvest and site preparation on sedimentation, stormflow and water quality. Sediment yields increased following silvicultural treatments but increases were small, short-lived and had little if any effect on site productivity. Erodibility of the mountain soils was low due to a number of factors: loamy surface textures with high infiltration rates, natural rock pavements on soil surfaces, high levels of surface detention storage and an abundance of coarse and fine surface organic matter left on site after silvicultural treatments. Stormflow volumes and peakflows from larger storms were not affected by treatments, but responses were measured for smaller storms during drier seasons. The total suspended solids (TSS) concentrations of stormflow were increased following treatments but the duration of elevated TSS levels was small and the effects short lived.

154. Miller, R. L. Trends in Nonpoint Source Pollution Regulation and Policy: How Should Forestry Respond? In: Blackmon, B. G. Proceedings of Forestry and water Quality: A Mid-South Symposium.; 1985 May 8; Little Rock, AR. Department of Forest Resources, University of Arkansas, Monticello; 1985: 1-17.

Forestry nonpoint source (NPS) water quality management improvements to date are substantial. The 208 experience resulted in basic, permanent improvements in education, understanding and capabilities across the board among the organizations and professionals involved. EPA has moved to more realistic objectives and a policy of cooperative partnership with other agencies and NPS managers. However, other developments point to a triad of critical and persistent problems: (1) widespread misconceptions and simplistic ideas about technical and social aspects of forestry

NPS management; (2) unsound regulations on water quality standards and forest practices; and (3) increasing dominance of legal processes in policy and management decision making. Our forestry representatives on the administrative and legislative firing lines and state and federal administrative agencies, including EPA, need additional supporting actions directed at these problems. This support can best be provided through more systematic and coordinated joint action planning of a strategic nature. Such a strategic program analysis should result in several programs of action (substrategies). One such substrategy should be a joint approach by agency/university/industry professionals to identify and produce professional papers on high-priority issues. Outlines of relevant aspects and questions on two basic issues--practical requirements in water quality standards regulations, and the factors that should be considered in regulatory versus nonregulatory program choices--are presented.

155. Mississippi Forestry Commission. Mississippi's Best Management Practices Handbook. : Mississippi Forestry Commission; 1989. 33p.

Mississippi has 16,981,000 acres classified as forest land and it is estimated that some type of forest activity occurs on 656,008 acres annually in the state. This represents approximately 4 percent of the state's forest land. Most streams originate or course through these forests and are sources of water supplies, prime recreation and other high water quality uses. Because of this, silvicultural practices should incorporate adequate measures to protect water quality. The only practical approach for reducing the non-point source pollution from forest activities is the use of preventive best management practices. The purpose of this handbook is to recommend and describe such practices for Mississippi's conditions of climate, soils and topography. Most BMPs involve the application of sound conservation principles which not only minimize water pollution, but are also consistent with economic objectives. It is recommended that those involved in carrying out these forest practices voluntarily use the BMPs. Since this is an iterative process it will be necessary to review and report how well these BMPs are being followed and their effectiveness in maintaining water quality.

156. Mississippi Forestry Association. Silvicultural Best Management Practices for Mississippi. : Mississippi Forestry Commission; 1989. 12p.

The Water Quality Act of 1987 (WQA) states: "It is the national policy that programs for the control of nonpoint sources of pollution be developed and implemented in an expeditious manner so as to enable the goals of this act to be met through the control of both point and nonpoint sources of pollution." Further, the Nonpoint Source (NPS) provisions in the Clean Water Act (CWA) are defined as follows: "NPS pollution is caused by diffuse sources that are not regulated as point sources and normally is associated with agricultural, silvicultural and urban run-off, run-off from construction activities, etc. Such pollution results in the human-made or human-induced alteration of the chemical, physical, biological, and radiological integrity of water (emphasis added)." Obviously, the forest resource is vital to the welfare of the people of Mississippi as it is very significant in the State's economy and environment. Therefore, sound forestry practices are critical and very important to the people of Mississippi. Past forest management techniques have elevated Mississippi forests to a high degree of productivity. Now the WQA makes it necessary to consider water quality as well in the silvicultural business. Accordingly, Best Management Practices (BMPs) are hereby set out as recommended guidelines to encourage the utlization of silvicultural practices which will control water pollution from NPS and at the same time be economically feasible for all forest landowners in Mississippi. The term "BMP" used herein references a set of suggested BMP's which could be appropriate to control, or minimize, the NPS water pollution at a given forest practice site. It should be understood that the BMPs contained herein are not intended to be applicable or all inclusive in every particular situation, nor the most effective and practicable alternatives in a particular situation. The application of the site specific BMP can only be made through proper analysis of the specific site by persons with the necessary technical skills. However, the voluntary BMP's set out herein will, in the vast majority of situations, be applicable and will adequately protect Mississippi streams from NPS pollution potentially caused by silvicultural activities. The success of silvicultural practice in Mississippi depends upon mutual cooperation and trust between landowners, industry, regulatory agencies and the general public. All these parties have a secured interest in good forest management as it relates to water quality. Accordingly, the BMP's herein offered are encouraged to be exercised through a voluntary program under the premise that knowledge and responsbile actions by the affected parties can prevent the need for additional governmental regulations while providing the necessary water quality protection mandated by the WQA.

157. Moore, D. G. Effects of Forest Fertilization with Urea on Stream Water Quality -- Quilcene Ranger District, Washington. Pacific Northwest Forest and Range Experiment Station: USDA Forest Service; 1975; Research Note PNW-241. 9p.

Aerial fertilization of two units on the Quilcene Ranger District of the Olympic National Forest with urea at 224 kilograms nitrogen per hectare (200 pounds nitrogen per acre) in April 1970 provided the opportunity to monitor water quality in small streams immediately adjacent to the treated areas. Applied fertilizer did reach surface streams in the form of urea-, ammoia-, and nitrate-nitrogen, but maximum concentrations measured were well below established permissible limits for public water supplies. Concentratios of urea-N never reached 1.0 part per million, ammonia-N increased only slightly above background, and the highest level of nitrate-N found was 0.121 part per million. Fertilizer nitrogen entered streams only in the form of nitrate after the first 3 weeks, and 95 percent of the total loss over 7 months occurred within the first 9 weeks after application. Fertilizer nitrogen lost during the 7-month monitoring period was about 0.25 percent of the total applied. Introduction of these small amounts of nitrogen into forest streams spread out over a period of several weeks should have little measurable impact on eutrophication.

158. Moore, D. G. Impact of Forest Fertilization on Water Quality in the Douglas-Fir Region -- A Summary of Monitoring Studies. In: Proceedings of the 1974 National Convention of the Society of American Foresters.; 1974 Sep 22; New York, NY. ; 1974: 209-219.

159. National Council of the Paper Industry for Air and Stream Improvement. 1979 Review of the Literature on Forest Management Practices, Hydrology, and Water Quality Protection and Management. : NCASI; 1980; Stream Improvement Technical Bulletin No. 330. 60p.

160. National Council of the Paper Industry for Air and Stream Improvement. 1980 Review of the Literature on Forest Management Practices, Hydrology, and Water Quality Protection and Management. : NCASI; 1981; Stream Improvement Technical Bulletin No. 345. 87p.

161. National Council of the Paper Industry for Air and Stream Improvement. 1981 Review of the Literature on Forest Management Practices, Hydrology, and Water Quality Protection and Management. : NCASI; 1982; Technical Bulletin No. 370. 92p.

162. National Council of the Paper Industry for Air and Stream Improvement. 1982 Review of the Literature on Forest Management Practices, Hydrology, and Water Quality Protection and Management. : NCASI; 1983; Technical Bulletin No. 407. 73p.

163. National Council of the Paper Industry for Air and Stream Improvement. 1983 Review of the Literature on Forest Management Practices, Hydrology, and Water Quality Protection and Management. : NCASI; 1986; Technical Bulletin No. 507. 73p.

164. National Council of the Paper Industry for Air and Stream Improvement. 1984 Review of the Literature on Forest Management Practices, Hydrology, and Water Quality Protection and Management. : NCASI; 1986; Technical Bulletin No. 510. 67p.

165. National Council of the Paper Industry for Air and Stream Improvement. Long-Term and Broad-Scale Water Quality Planning and the Use of Environmental Audits in Forest Management Programs. : NCASI; 1988; Technical Bulletin No. 541. 41p.

166. National Council of the Paper Industry for Air and Stream Improvement. Measuring and assessing the effectiveness of alternative forest management practices on water quality. : National Council of the Paper Industry for Air and Stream Improvement; 1981 Aug; NCASI Technical Review Bulletin No. 353.

167. National Council of the Paper Industry for Air and Stream Improvement. Research on the effects of forest harvesting, drainage, mechanical site preparation, and prescribed fire on water quality. New York, New York: National Council of the Paper Industry for Air and Stream Improvement; 1984 Sep; NCASI Technical Review Bulletin No. 442.

Contains multiple papers.

168. National Council of the Paper Industry for Air and Stream Improvement. A review of current knowledge and research on the impact of alternative forest management practices on receiving water quality. New York: National Council of the Paper Industry for Air and Stream Improvement; 1979; Technical Bulletin No. 322. 141 pages.

169. Neary, D. G. Effects of Pesticide Applications on Forest Watersheds. In: Coweeta 50th Anniversary Symposium; 1984 Oct 15; Athens, GA. ; 1984. 33p.

This paper summarizes research from the Coweeta Hydrologic Laboratory which shows the effects of pesticide application on streamflow, water quality, and biological processes. Most of the research emphasis has been on water quality. Some of the basic hydrological investigations have used herbicides to reduce tree basal area or eliminate vegetation. Studies in the last 5 years have begun to investigate the impacts of pesticides in aquatic and terrestrial species distributions, diversity, and nutrient and energy flux. Early water quality studies in the 1960's involved DDT, atrazine, 2,4-D, and paraquat. More recent studies have involved the herbicides picloram, hexazinone, and the insecticide methoxychlor. No long-term water quality problems have been produced by the infrequent application of pesticides.

170. Neary, D. G. Effects of Pesticide Applications on Forested Watersheds. In: Forest Hydrology and Ecology at Coweeta. New York: Springer-Verlag; 1988: 326-337.

Although Coweeta has not emphasized research on the impact of pesticides on forest watersheds, some fascinating results on the physical, chemical, and biological effects of herbicides and pesticides have been generated in the past 20 years. These findings come from studies using herbicides or insecticides to achieve some other objective, or from a few recent studies aimed specifically at the fate of herbicides in forest ecosystems.

171. Neary, D. G.; Bush, P. B.; Grant, M. A. Water Quality of Ephemeral Forest Streams After Site Preparation With the Herbicide Hexazinone. Forest Ecology and Management. 1986; 14(1): 23-40.

Four small watersheds (1 ha) in the upper Piedmont of north Georgia were treated with 1.68 kg/ha active ingredient of hexazinone pellets. Residues in stormflows peaked in the first storm (442 mg/m3), declined rapidly thereafter, and disappeared within 7 months. Loss of hexazinone in stormflow averaged 0.53% of the applied herbicide. Suspended solids concentrations in runoff from the treated watersheds averaged 50.4 +- 7.9 g/m3 and were slightly more than those of the control (36.4 +- 5.4 g/m3). Total sediment yields were increased by a factor of 2.5 due to increased runoff associated with site preparation using herbicide and salvage logging. However, sediment loadings remained below those produced by mechanical techniques and well within levels common in relatively undisturbed forests. Hexazinone treatment produced a large increase in NO3-N concentrations (peak of 5328 mg/m3), but NO3-N levels returned to normal within 2 years. Data indicate that hexazinone may have produced some stimulation of nitrifying bacteria. Cation concentrations increased 30-100% as a result of hexazinone application, but these increases were also transient. Overall, water quality changes were small and short-lived.

172. Neary, D. G.; Michael, J. L. Effect of Herbicides on Soil Productivity and Water Quality. In: Final Environmental Impact Statement: Vegetation Management in the Coastal Plain/Piedmont, Volume II, Appendix C. Atlanta, GA: USDA Forest Service; 1988; Management Bulletin R8-MFB-23. 24p.

The purpose of this paper is to review the effects of herbicides on soil productivity and water quality. This is accomplished by discussion of herbicide characteristics, applications, and environmental interactions as they influence effects on soil productivity and surface and ground water quality. Soil productivity effects are discussed in a general context. In regard to water quality, specific information and research results from southern studies are used, where possible, for the individual herbicides considered in this EIS.

173. Neary, D. G.; Michael, J. L. Effect of Sulfometuron Methyl on Ground Water and Stream Quality in Coastal Plain Forest Watersheds. Water Resources Bulletin. 1989; 25(3): 617-624.

Sulfometuron methyl (methyl 2-llll(4,6-dimethyl-2-pyrimidinyl)a-mino)carbonyl)amino)sulfonyl)benzoate) was applied by a ground sprayer at a maximum labeled rate of 0.42 kg ha-1 a.i. to a 4 ha Coastal Plain flatwoods watershed as site preparation for tree planting. Herbicide residues were detected in streamflow for only seven days after treatment and did not exceed 7 mg m-3. Sulfometuron methyl was not detected in any stormflow and was not found in any sediment (both bedload and suspended). Sampling of a shallow ground water aquifer, <1.5 m below ground surface, did not detect any sulfometuron methyl residues for 203 days after herbicide application. Lack of herbicide residue movement was attributed to low application rates, rapid hydrolysis in acidic soils and water, and dilution in streamflow.

174. Neary, D. G.; Swank, W. T.; Riekerk, H. An Overview of Nonpoint Source Pollution in the Southern United States. In: Hook, D. D.; Lea, R., eds. Proceedings of the Symposium: The Forested Wetlands of the Southern United States.; 1988 Jul 12; Orlando, FL. Southeast Forest Experiment Station, Asheville, NC: USDA Forest Service; 1989: 1-7.

This paper examines nonpoint source pollution (NPSP) in the thirteen states of the Southern Region. The definitions, sources, types, and trends of NPSP are discussed. NPSP is of particular concern to wetlands because it is difficult to manage and most states have little knowledge of the effects on wetlands. Information is very limited on the cumulative effects of different NPSP sources on wetlands. Where water quality is deteriorating, NPSP is frequently the major cause. Best management practices implemented by local and state agencies provide the best means of controlling NPSP.

175. Neary, Daniel G.; Bush, Parshall B.; Michael, Jerry L. (USDA Forest Service; University of Georgia; USDA Forest Service). Fate, Dissipation and Environmental Effects of Pesticides in Southern Forests: A Review of a Decade of Research Progress. Symposium on Pesticides in Forest Management, 11th Annual Meeting; 1990 Nov 11; Arlington, VA. ; Environmental Toxicology and Chemistry, Vol. 12: 411-428.

Ten years of watershed-scale research has been conducted on the fate of forestry-use pesticides in forested catchments under mainly operational conditions throughout the southern United States. Studies have evaulated chemicals such as hexazinone, picloram, sulfometuron methyl, metsulfuron methyl, azinphosmethyl, triclopyr, carbofuran, lindane, malathion, fenvalerate, copper-chronium-arsenic, and pentachlorophenol. Off-site movement in stream flow, leaching to ground water, and thermal combustion have been examined. Model verifications of pesticide fate and dissipation and risk analyses have been conducted using simulation models such asa GLEAMS, CREAMS, and PRZM. Field study data indicate that movement is controlled by the main hydrologic pathways (e.g., surface runoff, infiltration, interflow, and leaching below the root zone). Peak residue concentrations tend to be low (<500 ug/L), except where direct applications are made to perrennial streams or to ephemeral channels, and where buffer strips are not used and do not persist for extended periods of time. Indirect effects noted from the use of pesticides in forested watersheds include temporarily increased nitrate nitrogen losses, reduced sediment yields, temporal changes in terrestrial invertebrate abundance, reduced plant diversity, and changes in particulate organic matter transport in streams. Very limited cumulative effects research has been conducted. The effects of increasing watershed size on herbicide concentrations and the impact of nonforestry pesticides on fish have been examined. Analyses conducted in regional environmental impact statements indicate that the low concentrations and short persistence of forestry pesticides in surface and ground water do not pose a significant risk to water quality, aquatic biota, or human health.

176. Neuman, L. Silviculture and best management practices. In: Erosion control: You're gambling without it; 1987 February 26-27. : International Erosion Control Association; 1987: 145-155.

It has been documented that certain forest practices on some sites impact water quality. This paper discusses these impacts, the management practices that may cause them, and the management techniques that can be used to prevent or minimize them. It provides a brief discussion of the silviculture/water relationship in Florida as it is currnetly understood, and offers recommendations that, if followed, will protect surface water quality and conserve site productivity. This paper describes the method used to match Best Management Practices (BMPs) with various forest conditions in Florida.

177. Norris, L. A.; Moore, D. G. Forests and Rangelands as Sources of Chemical Pollutants. In: Non-Point Sources of Water Pollution; Corvallis, OR. Water Resources Research Institute: Oregon State University; 1976: 17-35.

Technological revolution in American agriculture has produced a 35 percent increase in farm output with a 45 percent reduction in farm labor despite an 11 percent reduction in cropland acreage since 1940 (Barton, 1966). Forestry technology must undergo a similar revolution to provide the products and services the Nation demands from our forests and rangelands. Our past preoccupation with projected needs of the Nation for wood fiber obscured the increasing demands for forage, water, wildlife, and areas for purely recreational purposes. All these needs must be satisfied, so we must compensate for our decreasing production base for wood products by markedly increasing the productivity of each acre of forest land devoted primarily to timber production. Chemicals have played an important role in the success story of modern American agriculture. These same tools -- fertilizers, insecticides, and a host of other pest control agents -- are equally important in meeting our timber needs. The widespread use of chemicals, however, cannot proceed without adequate consideration of their possible impact on environmental quality. We must know in advance the consequence or hazard from each practice involving the use of chemical tools. The hazard of using an herbicide is the risk of adverse effects on nontarget organisms. Two factors determine the degree of hazard: (1) the toxicity of the chemical and (2) the likelihood that nontarget organisms will be exposed to toxic doses. Toxicity alone does not make a chemical hazardous. The hazard comes from exposure to toxic doses of that chemical. Even the most toxic chemicals pose no hazard if organisms are not exposed to them. Therefore, an adequate assessment of the hazard from the use of any chemical requires consideration of both the likelihood of exposure and the toxicity of the chemical (Norris, 1971).

178. Nutter, W. L. Erosion and Sedimentation as Related to Intensive Timber Management in the Southeast. In: Ashton, P. M.; Underwood, R. C., eds. Southern Regional Conference on Non-Point Sources of Water Pollution.; 1975 May 1; Blacksburg, VA. VPI and State University, Blacksburg, VA: Virginia Water Resources Research Center; 1975: 153-155.

The objective of intensive timber management is to maximize fiber production while maintaining site quality. The primary activities that may lead to accelerated erosion and sedimentation are access-system design and location, harvesting, site preparation, and planting. Other causal factors in some instances include fire protection and suppression activities. Whenever accelerated erosion and sedimentation do occur, the forest manager must be concerned with two consequences: degradation of site productivity potential, and stream water quality. In most cases the necessary technology, when coupled with common sense, is available to minimize accelerated erosion and sedimentation following intensive forest activities. The question of how much sediment delivered to streams is permissible remains unanswered. However, forest-resource managers do have the ability to maintain sediment-delivery rates below those found with good agricultural practices in the same region, even though the forest activities are most frequently on steeper land. In addition, the frequency with which any one site will be disturbed is on the order of once every 15 to 25 years, whereas most agricultural land is disturbed at least once a year. Although there is no soil loss prediction equation that may be applied to disturbed forest land, familiarity with the Universal Soil Loss Equation (Wischmeier and Smith, 1965) as applied to agricultural fields provides insight into the factors most important in the detachment, transportation, and deposition of soil particles. The factors are vegetative cover, soil erodibility, rainfall energy, land slope, and length and type of conservation practice (such as contour plowing, terracing, etc.). In the Southeast, anywhere from 50 to 75 percent of the total annual rainfall energy occurs during the summer months, when the frequency of high-intensity convectional storms is greatest. If intensive forest activities are planned so only a minimum of mineral soil is exposed during these months, soil particle detachment would be drastically reduced. Additionial possibilities are obvious for reducing sediment production through an understanding of the soil loss equation. Among them are restricting intensive activities where soil erodibility and/or slope are high, and operating along the contour. Although the Universal Soil Loss Equation is not applicable to watersheds, application of the concepts of source-area hydrology (Hewlett and Nutter, 1970) will lead to further reduction in the delivery of sediment to the stream channel. Source area hydrology recognizes the expanding and shrinking nature of the stream channel system during a storm. These expanding channels must "reach out" to collect sediment and deliver it to the perennial channel. the source area, and hence the extensiveness of channel expansion, is a function of basin morphology, antecedent moisture conditions, and the intensity and duration of the storm. The majority of the sediment load in the perennial channel due to accelerated erosion is delivered by the channelized flow in the expanded channel system. Therefore, if the variable source area is identified and major disturbance activities are not permitted in the area, the chance of sediment delivery to the perennial stream channel is greatly reduced. Among current intensive timber-management practices, access systems rank highest in sediment-production potential, followed in order by site preparation, harvesting, and planting. Access systems often are inadequately designed and improperly located, resulting in high rates of sediment delivery to the stream channel. To further compound the problem, the access system often must be overdesigned to accommodate highway-type vehicles, and frequently these vehicles are operated when the roads are too wet. All of these factors lead to more extensive disturbances in concentrated drainage problems than necessary. Frequently 75 to 90 percent of the sediment delivered to the perennial stream channel is from the access system, and delivery often continues long after the operation is closed down. Types of site preparation vary with the terrain and agency practice, but all have the common objectives of preparing a planting bed, reducing woody and herbaceous competition, and reducing fire hazard. Sediment delivery to the perennial stream channel can be minimized if a technique is selected that: (1) is compatable with the site; (2) leaves as much organic matter intact over mineral soil as possible; (3) is scheduled to reduce exposure during periods of high rainfall energy, and (4) is restricted in the sensitive source areas. Harvesting activities and related erosion have been studied intensively over the years. These investigations indicate that the three foremost erosion-control practices are: (1) keeping skid trails diffused and running upslope; (2) keeping equipment out of stream channels and crossing streams only with improved structures which are removed at the end of harvesting, and (3) maintaining organic layer over mineral soil whenever possible. Planting activities, when conducted sensibly using conservation practices similar to those used in agriculture, will not cause any increase in erosion. The question that still remains is, "How much sediment delivery to stream channels can be tolerated?" Sufficient information is available to the forest-resource manager to allow control of erosion and sediment delivery to the perennial stream channel. In many cases the application of common sense is all that is necessary to keep erosion within tolerable limits. Will erosion and sediment controls lead to higher costs? Likely not, particularly if the overall goal of maintaining site quality is fundamental to the management scheme. In fact, many of the practices that go hand in hand with reduced sediment production are less costly in terms of wear and tear on machinery even though there may be a slight increase in operating time.

179. Nutter, W. L.; Douglass, J. E. Consequences of Harvesting and Site Preparation in the Piedmont. In: Tippin, T., ed. Proceedings: A Symposium on Principles of Maintaining Productivity on Prepared Sites; 1978 Mar 21; Mississippi State University. Southern Forest Experiment Station, New Orleans, LA: USDA Forest Service; 1978: 65-72.

Piedmont soils suffered years of abuse under agriculture. Now stabilized under forest, these sites are subject to change by harvesting and site preparation. Increased erosion and lowered water quality may occur as a result. These changes can be controlled if the manager specifies conservation practices and the amount of mineral soil that can be exposed during harvest and regeneration. Methods of site preparation applied in the Piedmont need to be reexamined in light of specific silvicultural objectives and disturbance created by various methods.

180. O'Hayre, Arthur P., Assistant Professor of Forest Hydrology (Yale School of Forestry & Environmental Studies). Forestry Nonpoint Source Pollution: Recent Results and Possible Directions for Research in the North. in: U.S. Forestry and Water Quality: What Course in the 80's?; 1980 Jun 19; Richmond, VA. Washington, DC: Water Pollution Control Federation: 75-91.

The research approaches for assessing silvicultural non point source pollution are common to all regions. For the purpose of discussion I have categorized these approaches as direct assessments, indirect assessments, and modeling studies. I intend to present the results of research using these approaches that have been carried out in what may be considered the Northern Hardwood Region as outlined in Figure 1. I will also suggest some directions for research which may improve the efforts on silvicultural non point source pollution assessment and managemewnt. Water quality characteristics generally assumed to be potentially altered by timber harvesting include stream sediments, stream temperature and nutrients (U.S. Environ. Prot. Agency 1973). I would add aquatic ecology to that list even though it is highly dependent upon the other variables.

181. Ohlander, Coryell A. (Rocky Mountain Region, US Forest Service, Denver, CO). Clean Water Act - Monitoring and Evaluation. in: Water Resources Analyses. Region 2, Denver, CO: USDA FS; 1992 Dec. CWA1-1 - CWA2-31.

Part 1. Legal Framework. Perspective: Failure to meet Clean Water Act requirements in a given watershed, transfers the effective land use control in that watershed to the State water quality control agency. That is the effect of Sec 319 of the Clean Water Act. CWA S 319, "Nonpoint Source Management Programs", is a new section added in 1987 that generates a biennial State Assessment and Management Program document. The assessment identifies 1) waters that will likely fail or currently fail to meet the Clean Water Act goals; 2) activities that contribute to the problem; and 3) possible best management practices and measures that will improve the conditions for impaired watersheds. The State Management Program is a specific multi-year action plan that schedules coordination and implementation (1). State water quality plans also meet certain minimum federal requirements (40 CFR 131.6) before they can be approved by EPA. The plan must set standards that are consistent with CWA goals and procedures; set criteria to protect designated uses; must provide for antidegradation; must show official certification; and provide sufficient scientific background to support program implementation. In times of dwindling resources and expanding litigation, the best approach is to conduct activities in ways that the Clean Water Act goals are achieved; that small problems are identified early and fixed; and to rationalize pollution control expenditures in terms of measurable results. In a broad context, land use planning and NEPA environmental analysis continues to demand detailed analysis of water quality issues (2 3 4 5 6 7 8). Failure to respond adequately to legal mandate is an easy challenge that can, and has, upset plan implementation (9). The "enforcement program for mitigation" in the Record of Decision (40 C 1505.2) is particularly exposed to challenge; it must be technically competent, legally defensible, and accurately reported.

182. Ohlander, Corky, Hydrologist (USDA Forest Service, Lakewood, CO). Stream Reach Review - Clean Water Act Monitoring. in: Water Resources Analyses - T-Walk, Water Quality Monitoring Field Manual & Tables, Assessment Review. : USDA Forest Service, Region 2; 1993 Feb. 26 pages.

183. Packer, Paul E. Forest Treatment Effects on Water Quality. Sopper, William E.; Lull, Howard W. Lull. Forest Hydrology; 1910 Aug 29; University Park, Pennsylvania. Pennsylvania State University: Symposium Publications Division, Pergamon Press: 687-699.

Most water flowing in our streams comes from forested watersheds. With continually increasing demands for high-quality water, we need to know how forest management activities affect the quality of water supplies. As the gentler forest lands become used more intensively, and as timber harvest activities extend further into rugged terrain, the opportunities for damage to water quality increase as a result of destruction of vegetation and disturbance of soil. An important job of watershed management research is to gain understanding of the hydrologic and erosional behavior of forest lands so that such management objectives as increasing water yields can be attained with a minimum increase in stream sedimentation. Research to determine the effects of forest treatments associated with timber harvesting has shown that: (1) undisturbed forests produce only small amounts of sediment and a streamflow usually suitable for drinking; (2) with the possible exceptions of substantial increases in streamflow temperatures and some increases in streambank erosion caused by higher streamflow peaks, timber cutting does not adversely affect water quality; (3) logging, or skidding of logs from forests, can sometimes increase sedimentation considerably, depending upon the location and drainage of skidways, the erodibility and stoniness of soils, and the rapidity of vegetation of skidways; (4)

roads that are inadequately drained or are located too close to streams are the main cause of deterioration of water quality in forests.

184. Packer, Paul E. Management of forest watersheds and improvement of fish habitat. Transactions of the American Fisheries Society. 1957; 87: 392-397.

Management of forest watersheds in the western United States for protection against floods and sediment and to improve water yields can also be very beneficial in fishery management. Some of the important hydrologic processes that operate on watersheds are discussed. The principal kinds of watershed protection and water yield improvement problems are outlined and discussed in relation to maintenance of desirable fish habitat. Need for research to determine quantitative hydrologic relationships on watersheds and develop methods of forest management for better regulated and higher quality streamflow is emphasized.

185. PACKER, PAUL E.; HAUPT, HAROLD F. THE INFLUENCE OF ROADS ON WATER QUALITY CHARACTERISTICS. In: PROCEEDINGS, SOCIETY OF AMERICAN FORESTERS; 1965; DETROIT, MICHIGAN. INTERMOUNTAIN FOREST AND RANGE EXPERIMENT STATION, LOGAN, UTAH.: USDA FOREST SERVICE: 112-115.

ROAD SYSTEMS NEEDED TO SERVE INTERREGIONAL TRAFFIC AS WELL AS LOCAL USES, INCLUDING THOSE FOR TIMBER HARVESTING, INCREASE THE POTENTIAL FOR DAMAGING THE HIGH QUALITY OF WATER. EXAMPLES ARE CITED WHERE POORLY-BUILT ROADS PRODUCE LARGE AMOUNTS OF SEDIMENT. WELL-BUILT FOREST ROADS CONTRIBUTE SOME SEDIMENT AFTER CONSTRUCTION; BUT, BECAUSE OF GOOD LOCATION AND DESIGN CHARACTERISTICS WITH RESPECT TO DRAINAGE, EROSION SCARS HEAL RAPIDLY. THE IMPORTANCE OF KEEPING EVEN SMALL QUANTITIES OF SEDIMENT OUT OF STREAM CHANNELS HAS BEEN STRESSED REPEATEDLY BY FISHERY BIOLOGISTS. TURBID STREAMFLOW MAY DRASTICALLY REDUCE AQUATIC FAUNA AND THE HATCHABILITY OF FISH EGGS. WATERSHED SCIENTISTS HAVE OBSERVED THAT, WHEN WELL-CONSTRUCTED ROADS ARE LOCATED SOME DISTANCE FROM STREAMS, MUDDY OVERLAND FLOW DOES NOT REACH THE STREAM, BUT INFILTRATES HARMLESSLY INTO THE UNDISTURBED INTERVENING PROTECTIVE STRIP. ROAD LOCATION, DRAINAGE DESIGN, AND NATURE OF THE PROTECTIVE STRIP, THEREFORE, ARE ESSENTIAL FACTORS IN WATER-QUALITY CONTROL ON MANAGED FOREST LANDS. GUIDES FOR LOCATING AND DRAINING ROADS HAVE BEEN DEVELOPED FROM INVESTIGATIONS IN SPECIFIC LOCATIONS WHERE SOIL AND TERRAIN FACTORS WERE STUDIED. SIMILAR STUDY TECHNIQUES WOULD BE VALUABLE FOR DETERMINING THE INFLUENCE OF ROADS ON WATER QUALITY CHARACTERISTICS UNDER OTHER CONDITIONS OF SOIL AND TERRAIN. THIS ARTICLE HAS 17 REFERENCES.

186. Patric, J. H.; Aubertin, G. M. Long Term Effects of Repeated Logging on an Appalachian Stream. Journal of Forestry. 1977; 75(8): 492-494.

Watershed 2 on the Fernow Experimental Forest has been logged four times since the turn of the century. While little is known of how streams were affected by logging after 1901 or during World War II, the effects of diameter-limit cutting in 1958 and 1972 are well documented. Both cuts caused small increases in streamflow but had little effect on water quality by any criterion except turbidity, which was increased by poorly located and ill-managed logging roads. The evidence suggests that if responsible road practices are followed, continued diameter-limit cutting will not harm forest streams.

187. Patric, James H. Effects of wood products harvest on forest soil and water relations. Journal of Environmental Quality. 1980; 9(1): 73-80.

The effects of silvicultural treatments on streamflow have been evaluated for 20 years on a 34.7 ha forested catchment on the Fernow Experimental Forest, near Parsons, in north-central West Virginia. Selection harvest of 13, 8 and 6% of the basal area in 1958, 1963, and 1968, respectively, had negligible effect on any measured property of water. In 1969-1970, 31.7 ha were harvested by clearcutting, leaving a 3.0-ha protective strip of lightly cut forest extending about 20 m along both sides of the stream channel. This treatment had no effect on stormflow or stream temperature, but water yield increased 253 mm (38%) during the first year after cutting. Concentrations of sediment, nitrate, calcium, magnesium, potassium, and sodium in streamflow increased slightly. These effects on water quality were held to low levels by the protective strip and prudent management of logging roads. Subsequent cutting of the protective strip and clearing the stream channel in 1972 increased water yield 40 mm (9%) and raised stream temperature as much as 7.8 degrees C. Luxuriant regrowth over the entire watershed reduced all effects on water within 2 years after each treatment, and no effect from any treatment was measurable after 1977.

188. Patric, James H. Logging roads and water quality. Proceedings, Forest Eng. Workshop on Forest Roads; Morgantown, West Virginia. ; 1970: 1-4: 11-16.

189. Pelren, D. W.; Curtis, J. G.; George, D. B.; Adams, V. D.; Layzer, J. B. Effectiveness of the Tennessee Division of Foresty's Best Management Practices to Control Degradation of Aquatic Resources Due to Clearcutting in the Pickett State Forest. In: Coleman, S. S.; Neary, D. G., eds. Proceedings of the Sixth Biennial Southern Silvicultural Research Conference.; 1930 Oct; Memphis, TN. Asheville, NC: USDA Forest Service, Southeastern Forest Experiment Station; 1991; cGeneral Technical Report SE-70: 663-680.

The Tennessee Division of Forestry (TDF) was manadated to develop and implement best management practices (BMPs) for the protection of surface waters adjacent to timber harvest areas. A paucity of information exists on the effectiveness of BMPs to control the degradation of watersheds by silviculture activities in Tennessee. This study determined if conservation measures prescribed by the TDF would protect the Rock Creek watershed from impacts caused by clearcutting. Streams in the study area historically maintained excellent water quality of low nutrient and metals concentrations and alkalinity below detectable levels. Water chemistry (nutrients, solids, total organic and inorganic carbon, metals, and herbicides), benthic macroinvertebrates (diversity, density, and taxa richness), and fish production were studied at sites above, adjacent to, and below logged areas. Logging did not noticeably affect water quality or aquatic fauna in the Pickett State Forest.

190. Perkey, A. W.; Sykes, K. J.; Palone, R. S. Crop Tree Management in Riparian Zones. Morgantown, WV: USDA Forest Service, State and Private Forestry; undated.

Intro: The riparian zone is delineated on the basis of a transition between the aquatic and terrestrial characteristics of soil, water, vegetation, and landform. Certain aquatic and vegetative communities are totally dependent upon riparian areas for existence. These areas provide such beneficial functions as moderation of flood peaks, groundwater recharge, wildlife and fish habitat, timber and forage production, and recreation opportunities. Crop tree management is an appropriate tool to use in riparian zones if the management of trees in this sensitive area is consistent with landowner objectives. Individual aesthetic, timber, wildlife, and aquatic crop trees can be selected in accordance with specific crop tree selection criteria designed to accomplish landowner objectives and produce desired benefits. Crop tree management can be used as a means to protect mineral soil from excess disturbance and compaction, preserve forest floor, and prevent alteration of natural surface and subsurface waterflow paths. It also helps maintain vigorous and diverse vegetation, stream temperature regulation, and moist soil conditions beneficial to soil microbes. There are many advantages to using the crop tree management concept within riparian zones. Not only does it provide erosion and sedimentation control, but it also enhances aesthitics, provides high quality forest products, improves wildlife and fish habitat, and maintains water quality.

191. Pierce, R. S.; Hornbeck, J. W.; Likens, G. E.; Bormann, F. H. Effect of Elimination of Vegetation on Stream Water Quantity and Quality. : IAHS-AISH Publication 96; 1970. 311-328.

An experiment to determine the magnitude of possible increases of water yield and resultant changes in water quality was conducted in a mountainous forested drainage with glaciated soils and tight bedrock in central New Hampshire, USA. A 15.6-hectare watershed was cleared of all woody vegetation and treated for 3 years with herbicides to minimize regrowth. Streamflow increases ranged from 240 mm to 346 mm per water-year, the greatest increases occurring in late summer, normally a period of critical low flows. Stream water chemistry changed radically from before-treatment levels. Nitrate concentration increased by an average of 50 times and major cation levels rose three- to twentyfold. Particulate matter increased 9 times. Results of this study indicate a significant change in water quality and loss of nutrients from the treated watershed. Though we do not know how serious these effects may be on areas subject to conventional forest management practice, obviously they should not be ignored---and certainly there is an urgent need for additional forest practices and water yield improvement on water quality and nutrient loss.

192. Ponce, S. L. The Biochemical Oxygen Demand of Finely Divided Logging Debris in Stream Water. Water Resources Research. 1974; 10(5): 983-988.

The impact of Douglas fir needles and twigs, western hemlock needles, and red alder leaves on dissolved oxygen and thus on the quality of mountain stream water was examined. The mean COD, 90-day BOD, and BOD rate coefficients were, respectively, 454 mg 0 2/g, 110 mg 0 2/g, and 0.125 for Douglas fir needles, 947 mg 0 2/g, 110 mg 0 2/g, and 0.056 for Douglas fir twigs, 570 mg 0 2/g, 200 mg 0 2/g, and 0.049 for western hemlock needles, and 882 mg 0 2/g, 286 mg 0 2/g, and 0.047 for red alder leaves. The 90-day values of BOD and K 1, for the leaf material could be estimated accurately by tests of 20, 20, and 60 days, respectively, for Douglas fir needles, western hemlock needles, and red alder leaves. The BOD of leaf material exposed to fluctuating temperature exerted a 5-day BOD 4.0, 2.4, and 4.2 times greater than the standard temperature BOD 5 for Douglas fir needles, western hemlock needles, and red alder leaves, respectively. Toxicity of a leachate extracted from each species was determined on guppies and steelhead trout fry. The concentration of material needed to produce toxic effects was very high, so high, in fact, that oxygen depletion probably would be responsible for death long before the leachate effect. Data on oxygen depletion obtained in this study will be useful in developing a predictive model for water quality management on forest lands.

193. Putnam, William C. Implementation of best management practices. In: Schweitzer, Dennis L.; MacNaughton, Marcia J., Compilers. Proceedings National Workshop on Monitoring Forest Plan Implementation; 1990 May 14-17; Minneapolis, Minnesota. Washington D.C.: USDA-Forest Service, Land Management Planning; 1990 Aug: 92-97. 178 pages.

In order to meet legislative requirements, and various MOU's between the Forest Service and States, a reporting system is necessary to inform the States on implementation and effectiveness of BMP's installed on NFS lands. 1. Each Forest will prepare an annual summary report of the Forest BMP monitoring program as part of the overall Forest Plan Monitoring Report. This report will contain a summary of data from the Forest BMP Monitoring Program File. The Region will provide an electronic data handling procedure to minimize the time necessary to complete this task. 2.

The Region will prepare a compilation of the Forest reports for submission to the appropriate Federal and State regulatory agencies and concerned publics. 3. The Region will establish a BMP data base which will contain the on-site implementation and effectiveness ratings for each BMP that has been evaluated in a Forest BMP Monitoring Program File. Compilations of the ratings will allow tracking of each BMP and identify problem areas which would require modification of the BMP to make it more effective. 4. Water quality data collected from the instream portions of this monitoring program will be placed into the EPA STORET water quality data storage program.

194. Ralston, C. W.; Binstock, D. A.; Nguyen, V. P. The Santee Watershed Study: Does Prescribed Burning Affect Water Quality? In: Florida's Water Resources - Implications for Forest Management. 11th Spring Symposium for the Florida Section, Society of American Foresters. University of Florida; 1979: 76-82.

Projections of supply and demand for wood products by the U.S. Forest Service indicate substantial shortages of domestic timber beginning in 1990 if wood consumption and population growth trends continue as predicted. Since under favorable conditions it takes about 20 years to grow crops of wood fiber, forest industries are urging wider application of intensive forestry practices to increase forest productivity on their own lands and on a much larger aggregate area of woodlands in small private ownerships, mostly in the eastern United States. Promotional efforts have centered mainly on intensive culture of pine types in the southeast region where current timber yields are far below measured potential productivity. An intensive forestry program known widely as "The South's Third Forest" has industry sponsorship and the active support of state and federal forestry agencies in the South. The Third Forest System can be visualized as a vast network of tree farms featuring "clearcut and plant" silviculture on a 20-year rotation, i.e., a financial rotation with yields maximized by the use of genetically improved planting stock, fertilizers, drainage, and by use of prescribed burning and cultivation to control weeds.

195. Rashin, Ed; Bell, Johanna; Clishe, Casey (Washington State Department of Ecology). Effectiveness of Forest Road and Timber Harvest BMPs with Respect to Sediment-related Water Quality Impacts - Progress Report. Olympia, Washington: Washington State Dept. of Ecology; 1992 Oct. 21 pages.

This study to evaluate the effectiveness of certain forest road and timber harvest best management practices (BMPs) is being conducted by the Department of Ecology as a part of the Timber/Fish/Wildlife Cooperative Monitoring, Evaluation and Research Program (CMER). The project is sponsored by CMER's Water Quality Steering Committee (WQSC), and is funded jointly by CMER, the Department of Ecology, and the U.S. Environmental Protection Agency. Objectives of the project are: 1) to gather qualitative and quantitative information on BMP effectiveness by monitoring representative examples of BMP implementation; 2) to develop and apply criteria for determining whether water quality standards are met where forest practice-related sediment impacts are concerned; 3) to evaluate and describe the factors influencing BMP effectiveness; and 4) to determine whether certain BMPs require modifications in order to achieve water quality standards, and recommend such changes. The purpose of this Progress Report is: 1) to report on progress to date on the project, describe the study sites established, and discuss survey methodologies employed; 2) to describe study site selection criteria; and 3) to present a preliminary assessment of the sampling design. It was originally planned that this progress report would be prepared at the conclusion of the pilot phase. However, because of a delay in starting, the pilot phase of the project will continue through November of 1992.

196. Reinhart, K. G. Timber-Harvest Clearcutting and Nutrients in the Northeastern United States. Northeast Forest Experiment Station: USDA Forest Service; 1973; Research Note SE-170. 5p.

The effect of ecosystem disturbance on nutrients in the system has been receiving widespread attention. An appraisal of research results in the northeast indicates that timber-harvest clearcutting has not increased nutrient levels sufficiently to reduce water quality below drinking water standards. Losses of nutrients from clearcuttings in New Hampshire over a 2-year period were about 85 pounds per acre for nitrate-N and 80 pounds per acre for Ca. Losses in the central and southern Appalachians were far less. There is both need and opportunity for productive research on many aspects of nutrient flow in forested ecosystems.

197. Reinhart, K. G.; Eschner, A. R.; Trimble, G. R. ,. Jr. Effect on Streamflow of Four Forest Practices in the Mountains of West Virginia. Northeastern Forest Experiment Station: USDA Forest Service; 1963; Research Paper NE-1. 79p.

SUMMARY: After a 6-year calibration, four watersheds on the Fernow Experimental Forest were logged in 1957-58. Treatments ranged from a commercial clearcutting with unplanned logger's choice skidroads to a light selection cutting with planned skidroads on moderate grades. For the most part, the treatments did not seriously disturb the forest floor. Treatments resulted in a increase in annual flow, ranging up to 5 area-inches on the clearcut watershed the year after treatment. Flow increases fell into a logical pattern in relation to volume cut. Most of the flow increase came into the gfrowing season. In the 6-month period from May to October, 1959, for example, increases were 3.0, 1.8, 1.4, and 0.3 area-inches foe per-acre cuttings of 8.5, 4.2, 3.7, and 1.7 M b.m., respectively. Low flows were augmented, especially for the two heavily cut watersheds. Effect on high flows was variable. On the clearcut watershed some storm-period discharges in the growing season were more than doubled as a result of treatment and some snowmelt flows were reduced. Care in the logging operation was clearly reflected inwater quality. Maximum turbidities ranged from 56,000 ppm on the watershed with unplanned and undrained skidroads to 25 on the watershed with carefully planned skidroads. Even on the two watersheds with unplannned skidroads, turbidities were only high during and immediately after the logging operation. Effects of treatment are diminishing with time. Measurements on the watersheds are continuing in an effort to determine the duration of changes due to treatment and the effect of succeeding harvests on the partially cut watersheds.

198. Rice, R. M.; Tilley, F. B.; Datzman, P. A. A Watershed's Response to Logging and Roads: South Fork of Caspar Creek, California, 1967-1976. Pacific Southwest Forest and Range Experiment Station: USDA Forest Service; 1979; Research Paper PSW-146. 12p.

Conclusions: In summary we conclude that the study of roading and selective timber harvest in the watershed of the south fork of Caspar Creek suggests that: 1) the watershed appears representative of other harvested areas investigated in northwestern California, 2) the information gained in this study applies most directly to tractor yarded, partially cut second-growth redwood and old-growth timber of other species, 3) Disturbances from road building and logging changed the sediment/discharge relationship of the south fork from one which was supply dependent to one which was stream power dependent, resulting in substantial increases in suspended sediment discharges, 4) although road building and logging apparently increased debris basin deposits as well, the nature of the increase is much less clear. Lags in the movement of bed material through the stream system may be the confusing element, 5) the overall effect on site quality, as estimated by erosion or sedimentation, does not appear to be a cause for concern, and 6) road construction and logging appear to have resulted in increases in average turbidity levels (as inferred from suspended sediment increases) above those permitted by Regional Water Quality Regulations.

199. Richter, D. D.; Ralston, C. W.; Harms, W. R.; Gilliam, F. S. Effects of Prescribed Fire on Water Quality at the Santee Experimental Watersheds in South Carolina. In: Research on the Effects of Forest Harvesting, Drainage, Mechanical Site Preparation, and Prescribed Fire on Water Quality. : National Council of the Paper Industry for Air and Stream Improvement; 1984; NCASI Technical Bulletin No. 442: 29-39.

Summary: Precribed fires had few detectable effects on forest soils, nutrient cycling, and hydrologic systems of a pine-flatwoods watershed at the Santee Experimental Forest in the Francis Marion National Forest in South Carolina, a site of long-term watershed research by the US Forest Service and Duke University. Experiments were designed so that treatment effects would simulate responses of an operational southern pine forest, and it was concluded that nutrient fluxes from burned pine litter to ground and stream waters are not likely to have appreciable effects on the quality of waters that drain southern pine watersheds, especially those with fine-textured soils.

200. Richter, D. D.; Ralston, C. W.; Harms, W. R. Prescribed Fire: Effects on Water Quality and Forest Nutrient Cycling. Science. 1982; 215: 661-663.
Note: have it.

Prescribed fire, a practice applied annually to about 10 X6 hectares of forests in the southeastern United States, had limited effects on soils, nutrient cycling, and hydrologic systems of a Coastal Plain pine forest. Hydrologic fluxes of nitrogen, phosphorus, sulfur, and basic cations, from burned pine litter to ground and stream waters, are not likely to have appreciable impacts on water quality in the Atlantic and Gulf Coastal Plain.

201. Riekerk, H. Environmental Impacts of Intensive Silviculture in Florida. In: Ballard, R.; Gessel, S. P., eds. IUFRO Symposium on Forest Site and Continuous Productivity. Pacific Northwest Forest and Range Experiment Station, Portland, OR: USDA Forest Service; 1983; General Technical Report PNW-162: 264-271.

Five operational-sized watersheds were constructed in Florida's poorly drained flatwoods landscape. A 12-month calibration period was followed by four treatments, including a range of biomass removals and levels of intensity of site preparation for forest regeneration, plus a control. Biomass and nutrient removals, precipitation input, and runoff output were monitored for several years. The data show a rapid return of runoff increases and water quality degradation to baseline levels. Biomass nutrient exports represent the major pathway of nutrient losses. Conventional pulpwood harvesting did not significantly affect nutrient balances. Whole-tree harvesting and total-tree harvesting (including stumps) led to significant nutrient losses.

202. Riekerk, H. Water Quality Management in Flatwoods of Florida. In: Coleman, S. S.; Mace, A. C. ,. Jr; Swindell, B. F., eds. Impacts of Intensive Forest Management Practices Symposium Proceedings. School of Forest Resources and Conservation: University of Florida, Gainesville; 1982: 53-63.

Data are reported for a 4-year study of environmental impacts of two distinct pulpwood harvest and reforestation regimes in pine flatwoods watersheds. Normally acid runoff (pH = 4.0) was not greatly affected, but showed significant increases in potassium, calcium, and suspended sediments for 1 to 3 years after treatments began. Nutrient balance data generally showed nutrient accumulations, except for calcium, suggesting these practices to be within the resiliency range of the site. Whole-tree harvesting would create nutrient drains requiring soil amendments to prevent long-term site degradation.

203. Riekerk, H.; Korhnak, L. V. Environmental Effects of Silviculture in Pine Flatwoods. In: Shoulders, E., ed. Proceedings of the Third Biennial Southern Silvicultural Research Conference.; Atlanta, GA. : USDA Forest Service; 1985; General Technical Report SO-54: 528-535.

A series of watersheds and plots were established to evaluate the environmental effects of a range of silvicultural practices in the Lower Coastal Plain of Florida. The results showed significant, but short term, changes in stormflow, water yield, and water quality even after highly intensive harvesting and site preparation. Soil moisture in high density fuelwood plantations was reduced some because of rainfall interception. Suspended sediments, pH, and cation levels increased in association with stormflow. Nutrient losses were proportional to harvesting intensity suggesting longterm site degradation. Soil amendment with coal-ash, for fuelwood production neutralized the normally acid soil and runoff.

204. Riekerk, H.; Morris, L. A.; Lassiter, C. I. The Effect of Harvesting Flatwoods Forest on Water Quality and Nutrient Budgets. In: Florida's Water Resources - Implications for Forest Management. 11th Spring Symposium for the Florida Section, Society of American Foresters. : University of Florida; 1979: 108-120.

Concern about the impact of intensive forest management practices on multiple forest ecosystem values has resulted in the establishment of several research areas in the Florida Coastal Plain (Smith and Swindel, 1978). Evaluation of harvesting, slash burning, site preparation, and planting techniques with respect to water quality is the main focus for studies in the north-central Florida flatwoods landscape. Data for undisturbed forested conditions provided for a baseline reference to assess nonpoint source pollution (Riekerk et al., 1979). The purpose of this paper is to report on the initial effects of harvesting intensity on the hydrology and water quality of the calibrated watersheds. Future reports will incorporate information on subsequent treatment effects to be used by forest land managers and state regulatory agencies.

205. Riekerk, H.; Neary, D. G.; Swank, W. T. The Magnitude of Upland Silvicultural Nonpoint Source Pollution in the South. In: Hook, D. D.; Lea, R., eds. Proceedings of the Symposium: The Forested Wetlands of the Southern United States.; 1988 Jul 12; Orlando, FL. Southeastern Forest Experiment Station, Asheville, NC: USDA Forest Service; 1989; General Technical Report SE-50: 8-18.

Streamflow water quality data from intensive silvicultural practices in the southern United States are summarized and discussed with respect to regional differences of nonpoint source pollution and Best Management Practices. Suspended sediment production by silviculture was low in the mountains and lower coastal plain, but high in the Piedmont and upper coastal plain regions. This reflected an interaction between site preparation intensity and topographic relief. Cation nutrient export after harvesting in the mountains was increased by higher nitrate carrier-ion production and by more runoff. Nutrient exports in the Piedmont and upper coastal plain regions were controlled by the degree of soil disturbance and by the recovery rate of vegetation. Nutrient exports in the lower coastal plain were not much affected by intensive silviculture. Information gaps and research needs for upland nonpoint source pollution effects on wetlands are identified.

206. Riekerk, Hans; Swindel, Benee F.; Replogle, John A., Asst. Professor of Forest Hydrology; Research Forester; Research Hydraulic Engineer (University of Florida; SE Forest Experiment Station; US Water Conservation Laboratory). Initial Hydrologic Effects of Forestry Practices in Florida Flatwoods Watersheds. in: IMPAC Report. ; 1980 Jun; Volume 5 - Number 4. 24 pages.

Three watersheds were artifically isolated in poorly-drained pine flatwoods on sandy soils of the Lower Coastal Plain in north Florida. Recording flumes and automatic samplers were installed to assess quantity and quality of runoff. After 1 year of calibration monitoring two of the watersheds were harvested, site prepared, and replanted to pines. Practices imposed on Watershed 1 were designed to minimize site disturbance and consisted of a manual shortwood harvest, residue chopping, bedding, and planting. Practices imposed on Watershed 2 consisted of tree-length logging, stumping, burning, windrowing, harrowing, bedding, and planting. Annual water yields increased 39 percent and 122 percent from Watersheds 1 and 2, respectively, during the year of treatment. Statistical tests for alteration in water quality have not yet been conducted, but nutrient concentrations in the runoff remained low during the year of treatment. Nutrient balances generally show a significant net retention, except for acid hydrogen ions, even after harvest and regeneration. Suspended sediment production by the maximally disturbed watershed during the year of treatment was 18 kg/ha/yr. Bedload sediment production from all three watersheds was negligible and was not increased by either treatment.

207. Rishel, G. B.; Lynch, F. A.; Corbett, E. S. Seasonal Stream Temperature Changes Following Forest Harvesting. Journal of Environmental Quality. 1982; Vol. 11, no. 1: 112-116.

Exposing headwater streams to direct solar radiation by removing forest cover has the potential to cause drastic changes in streamwater temperature regimes. A study was conducted to evaluate the maximum potential impacts and to evaluate the effectiveness of management practices used to control these detrimental effects. The control watershed approach was utilized. A clearcut-herbicide experiment on a small, headwater stream increased maximum stream temperatures as early as February and as late as November. The average monthly maximum stream temperature increase was 4.4 degrees C. Stream temperatures above 21 degrees C occurred nearly every day during the summer. Stream temperatures above 25 degrees C were recorded as early as May. The highest stream temperature recorded was 32 degrees C. On an adjacent forested watershed, stream temperatures rarely exceeded 20 degrees C; the highest recorded temperature was 22 degrees C. Minimum stream temperatures on the clearcut-herbicided watershed increased an average of 2 degrees during the summer months, but were as much as 3.9 degrees C lower during the fall and winter months. Diurnal fluctuations in stream temperature were also increased. Diurnal fluctuations as high as 17 degrees C occurred on the clearcut-herbicided watershed compared with only 4 degrees C on the forested watershed. On an adjacent commercially clearcut watershed, where a buffer zone was left along the perennial stream channels, only slight changes in stream temperature were observed. The average monthly maximum stream temperature increase was <1 degree C; the highest temperature recorded was 23 degrees C. Minimum temperatures remained generally unchanged.

208. Roby, Ken; Rector, John; Furniss, Michael J. Investigating Water Quality in the Pacific Southwest Region. Best Management Practices Evaluation Program: A User's Guide. San Francisco, CA: USDA Forest Service, Region 5; 1992 May; BMPEP.

The objectives of the BMP Evaluation Program are to: -Assess the degree of implementation of BMPs; -Determine which BMPs are effective; -Determine which BMPs need improvement or development; -Fulfill Forest Land and Resource Management Plan BMP monitoring commitments; -Provide a record of performance for management of nonpoint source pollution in Region 5. Many people were consulted in 1989 and 1990 to determine what the BMPEP should include. Contributing were representatives from many of the Forests in California, EPA, State and Regional Water Quality Control Boards, Universities, Industry and Environmental Groups. Proposals were field tested in 1989, and again in 1990 on nine Forests representing the wide range of environmental conditions and management emphasis that exist on California's National Forests. The procedures went through many revisions, based on the results of field testing and comments from people who did the test evaluations. The procedures are refined to the point where they yield repeatable results based on readily collected information. The BMPEP has three primary components: Administrative Evaluations, On-Site Evaluations, and In-Channel Evaluationis.

209. Rothacher, Jack S. Managing forest land for water quality. In: Proceedings of the Joint FAO/USSR International Symposium on Forest Influences and Watershed Management; 1970; Moscow, U.S.S.R. Washington, D.C.: U.S. Government Printing Office; 1970: 232-244.

210. Sachet, J.; Keller, S.; McCoy, A.; Orr, T.; Wolf, N. An assessment of the adequacy of Washington's Forest Practices Rules and Regulations in protecting water quality. : Washington State Department of Ecology; 1980; DOE No. 80-7 and 80-7a.

One hundred two randomly selected Forest Practice Applications involving 219 practices conducted under the Washington Forest Practices Act of 1974 were subjectively evaluated for water quality impacts and level of operator compliance with regulations of the Act. Administration by state agencies, and effectiveness of the regulations in meeting water quality goals were also investigated. Field methods relied on visual observations during one-time visits to sites. Water quality samples were not collected. Instead, where problems were found, the degree of disturbance to vegetation, soils, and streambanks and channels was used to determine whether water quality impacts had occurred and the type of impact. The amount of material introduced into water or apparent changes in water quality on-site and down stream was considered in assessing the severity of an impact. Consequently, field evaluations focused on sediment and slash and debris impacts rather than problems as elevated water temperature or depressed oxygen levels. Water quality was well protected when forest operations were conducted in compliance with the regulations. Compliance was 80% when practices were compared with the requirements of the regulations. In the 20% of the instances where the regulations were not followed, water quality impacts were frequent. In these latter instances both operator compliance and regulatory agency administration need improvement.

211. Schultz, Bill. Montana - Forestry Best Management Practices Implementation Monitoring. in: The 1992 Forestry BMP Audits Final Report. Missoula, MT: Montana Department of State Lands, Forestry Division; 1992. 33 pages, A-1 - F-10.

The Best Management Practice (BMP) audit process is used to evaluate whether BMPs are being applied and whether they are effectively limiting non-point source pollution. In 1991, the Montana Legislature directed the Montana Department of State Lands (DSL) Forestry Division to evaluate forest practices for BMP implementation and report to the EQC before the 1993 legislative session. This report summarizes the findings of Montana's 1992 forestry BMP audits. A similar study and report was completed in 1990. Three teams conducted the audits. Each audit team was composed of six members: a fisheries biologist, a forester, a hydrologist, a representative of a conservation group, a road engineer, and a soil scientist. DSL used site selection criteria to choose 46 timber harvest sites harvested since 1990. The selection criteria limited the sample to those sites most sensitive to the practices that affect water quality. The audit teams evaluated a maximum of 58 practices at each site, rating application and effectiveness for each BMP on a 5-point scale. The audit teams evaluated up to 58 practices on 46 sites for a total of 2029 practices rated for BMP application. 87% of the practices rated on all sites met BMP requirements. Because practices vary greatly in their potential impact, the application of nine high risk BMPs was evaluated separately. 72% of the high risk BMPs met application requirements. High risk BMPs are among those most important for protecting watersheds. Most sites --40 of --46 had at least one minor departure from BMP application; 20 of 46 sites had at least one major departure. Non-industrial private lands averaged 11 departures per site, the highest among all ownership groups. The average for all ownership groups was six departures per site. The audit teams evaluated up to 58 practices on 46 sites for a total of 2029 practices rated for BMP effectiveness. 90% of the practices rated on all sites were judged to provide adequate protection. Of the nine high risk BMPs evaluated on each site 77% of the practices were rated as providing adequate protection. 32 of the 46 sites audited were producing minor, temporary impacts to the soil and water resource; 17 of 46 sites had at least one major, temporary or minor, prolonged impacts; 5 of the sites had at least one major, prolonged impact. The average number of minor, temporary impacts per site was 2.8; the average number of major, temporary or minor, prolonged impacts per site was 1.4; the average number of major, prolonged impacts per site was 0.4. On 21 of 36 audit sites, teams noted that a change in stream crossing design would have prevented or reduced sediment discharge. The average length of streambank left unshaded was 28 feet. Ground skidding through a perennial stream occurred on 2 of the 46 sites, although no damage was noted. The average streamside management zone was 53 feet wide. Overall, the wider the SMZ, the fewer impacts in the SMZ from harvest practices. The greatest departure from BMPs, and the most impacts, were associated with road drainage. The text includes a list on pages 26 and 27 of problematic BMPs and BMPs that are usually applied properly. State lands had a higher rating than other ownership groups in application and effectiveness of BMPs, although the desired number of high hazard sites were not available. Results from Federal (USFS and BLM) and industrial sites were similar and ranked second among the ownership groups. Non-industrial private ranked fourth.

212. Segall, B. A. The impact of Vacation Homes on National Forest Water Resources. Fort Collins, CO: Eisenhower Consortium; 1976; Bulletin 3. 19p.

The number of private homes and recreational developments is increasing rapidly on the borders of National Forests. Waste materials from separate vacation homes or recreational communities can degrade forest areas and constitute a health hazard to home owners and individuals utilizing the National Forest for recreational activities. Wastewaters entering streams and lakes without prior treatment or with conventional secondary sewage treatment diminish water quality and restrict the use of water resources and contiguous forest areas. In the semi-arid climate of Arizona, the problem is twofold. If wastewater is not sufficiently treated, diluted or disposed of in an innocuous manner, it is esthetically objectionable. But, wastewater and its nutrient constituents are valuable potential resources in a semi-arid area that can be used for plant growth both within developed areas and in surrounding forests. A series of studies were undertaken to determine the effects of second homes and related vacation development on the quality of streams and groundwater in the National Forests in Arizona. The initial study was undertaken at a vacation home subdivision under construction in Northern Arizona--Pinewood. The community borders the Coconino National Forest and is a heterogenous development of cabins, large homes, trailers and service businesses. Pinewood was selected for study because its composition and rate of growth appeared to be representative of development that is occurring and probably will continue to occur adjacent to National Forest areas in Arizona. The community is served by a sewerage system that conveys wastes from homes to a secondary sewage treatment plant. Collection and transmission of sewage to a point location enables assessment of flow quantities and chemical and biological waste water characteristics. Concentration of home sewage flows is in itself a most significant potential environmental hazard. A water reuse practice found frequently in the Southwest is utilized at Pinewood. Secondary effluent from the community's sewage treatment plant is used to water a golf course. The water, as well as the organic and nutrient materials present in the waste, are utilized for plant growth. There is a possibility that diluted wastewaters are recycled at Pinewood since the water supply for the area consists of wells which pump aquifers that underlie the golf course. A second study was conducted in Oak Creek Canyon, an area north of Sedona, Arizona, that is within the Coconino National Forest. The Canyon is a major recreational area in northern Arizona and numerous private homes, trailer parks and Forest Service campground and picnic areas are found along the banks of Oak Creek. Septic tanks and soil absorption systems are used exclusively in second home and trailer developments for sewage disposal. In public campground areas, the Forest Service maintains vault privies that are periodically pumped and the wastes transported by truck to landfill sites.

213. Shelby, B.; Brown, T. C.; Taylor, J. G. Streamflow and Recreation. Fort Collins, CO: USDA Forest Service, Rocky Mountain Forest and Range Experiment Station; 1992; General Technical Report RM-209. 27p.

Studies by social scientists, physical and biological scientists, and engineers of the relation between streamflow and recreation quality have employed a wide variety of methods. Nearly all studies found a similar, nonlinear relation of recreation to flow quality increases with flow to a point, but decreases for further increases in flow. Critical flow levels (points of minimum, optimum, and maximum flow) differ across rivers and activities. Many state laws and agency practices now provide for considering the effects of streamflow on recreation. Knowledge of the flow-recreation relation, and its accurate calibration in specific locations, is an important ingredient in the determination of wise streamflow policies.

214. Shepard, James P. Effects of Forest Management on Water Quality in Wetland Forests. NCASI, Gainesville, FL. 1992 Jun: 002-006.

Assessments of the effects of management practices such as drainage, fertilization, and harvesting on water quality in wetland forests were summarized from available literature and ongoing research. Drainage generally resulted in small increases in some water quality parameters, but did not adversely affect water quality. Fertilization of N and P resulted in a brief elevation in concentrations, but net exports from the site were small. Comparisons of pre- and post-harvest water quality in several forests detected few differences in concentrations. Elevated concentrations due to harvesting were generally small and transient.

215. Sidle, Roy C. Overview of cumulative effects concepts and issues. In: Proceedings 1989 national convention: forestry on the frontier; 1989 September 24-27; Spokane, Washington. Bethesda, Maryland: Society of American Foresters; 1990; Publ. 89-02: 103-107.

Clean water originating from forest lands is one of our Nation's most important renewable resources. The condition of these forests affects the quality, abundance, and stability of downstream resources and habitat by controlling the production of sediments and chemicals and influencing streamflow and water temperature. With the expanding use of forest resources, multiple human activities, including logging, grazing. recreation, mining, and road construction, may occur within a drainage basin. Land managers are being asked to mitigate or predict cumulative effects of these land uses distributed over the scale of a watershed and over long periods. The cumulative effects of multiple uses of forest lands and the interaction with natural processes present considerably more complex and challenging problems for land managers and researchers than past emphasis on single land use activities. The importance of this issue is implied by its inclusion in the 1989 Presidential Water Quality Initiative.

216. Skaugset, Arne. Assessing the effectiveness of California's forest practice rules. In: Industry, State, and Federal Programs designed to assess and protect water quality associated with managed western forests. New York, New York: National Council of the Paper Industry for Air and Stream Improvement; 1985 Jul(NCASI Technical Bulletin No. 466): 49-60. 60 pages.

217. Smart, M. M.; Jones, J. R.; Sebaugh, J. L. Stream-Watershed Relations in the Missouri Ozark Plateau Province. Journal of Environmental Quality. 1985; 14(1): 77-82.

Water chemistry and algal chlorophyll values in Missouri Ozark streams were more strongly related to land-use practices on the watershed than bedrock geology or soil association. In general, concentrations of nutrients, chlorophyll, and most major ions were lowest in streams draining forests, intermediate in streams draining pastures, and highest in streams draining urban areas. In streams draining both forest and pasture areas, there was an exponential increase in the concentration of total P, total N, NO3-N, Na+, Cl-, and suspended chlorophyll a with an increase in percent pasture area on the watershed. These relations help identify the relative importance of land use on water chemistry and algal chlorophyll values, explain differences among streams in the region and enable us to approximate the impact of forest-pasture conversion on streams not yet affected.

218. Smith, C. M. Riparian Afforestation Effects on Water Yields and Water Quality in Pasture Catchments. Journal of Environmental Quality. 1992; 21: 237-245.

The flow records for two pasture headwater catchments for 9 yr before, and 9 yr after riparian afforestation in one catchment were compared. Average rainfall was 1021 mm/yr. Riparian afforestation reduced water yields by 68 to

104 mm (21-55%) when the Pinus radiata stand was 8 to 10 yr old. Delayed runoff declined by 52 to 93 mm/yr (27-63%). Afforestation reduced the quickflow yield in 1 yr (22mm or 40%). Peak flows declined in small events, were not affected in medium-sized events, and may have increased in large events. The large reductions in yield indicate that the riparian zone had a disproportionately important influence on catchment hydrology. They are attributed to high transpiration losses from the riparian pine in seasons with water deficits, and higher than usual forest interception losses because of the small-scale planting. Streamwater sediment, total and dissolved N and P concentrations in these two catchments and another riparian afforested catchment were monitored for 2 yr. Concentrations were generally lower in the completely pastured catchment. Estimated annual sediment, total P, Kjeldahl N, and nitrate exports from the pasture catchment were 31 to 66%, 70%, 61 to 64% and 58 to 74% of those from the riparian afforested catchments in spite of a higher water yield. Possible explanations for the poor water quality in riparian afforested catchments are described including the lack of riparian wetlands, in-stream vegetation, and close riparian ground cover. The consequences of riparian afforestation in pasture catchments may not readily be predicted from the impacts of complete catchment afforestation.

219. Snyder, Gordon G. The effects of clearcutting and burning on water quality. Moscow, Idaho: University of Idaho; 1973; M.S. thesis.

This study was initiated to gain information concerning the interrelationships between the alteration of the forest ecosystem and changes in water quality in the northern Rocky Mountains. Specifically the objectives of the study were: (1) Evaluate the changes in water quality from forested lands resulting from clearcutting and subsequent burning of the slash; (2) Determine the effectiveness of buffer strips of undisturbed vegetation along the streams in reducing the changes of the water quality.
Three clearcuts of varying size, soil, and aspect located along streams in the Priest River Experimental Forest in northern Idaho were chosen as study sites. Water sampling stations were established on each creek upstream and downstream from the clearcut-burned areas. Buffer strips of natural vegetation were left along channels to minimize the effects of the clearcut-burned areas. Physical and nutrient comparisons between these two sampling stations with the buffer strip only showed significant increases in electrical conductivity, turbidity, suspended solids, bicarbonate, sulfate, potassium, calcium, and magnesium. The nutrients that did not indicate increases for either the without or with buffer strip comparisons were chloride, nitrate, and sodium.

220. Snyder, Gordon, Hydrology/Water Quality Project Leader, Watershed Systems Development Group (USDA Forest Service). Monitoring on Wilderness Water Quality. Watershed Management 1980. New York, NY: American Society of Civil Engineers; 1980; Volume 1.

A lake water quality study of the Anaconda-Pintlar Wilderness Area in Montana was established to develop methods a wilderness manager could use to address these problems: 1) assess public health hazard, 2) assessment of pristine conditions, and 3) estimation of trophic state index for future estimations of recreational carrying capacity of lake systems. Fecal coliform and fecal streptoccoci were tested as an indicator of recreational impacts and to check potability of the water. Factor analyses were used to help select "key" physical and chemical parameters for future management programs. These parameters plus, representative biological variables were then used as indicators in cluster analyses. From these results, a trophic state index is proposed that can be used in wilderness lake management. The methods presented are expected to be helpful in the wildland management as well as provide valuable insight into the recreational/water quality problems that may exist in high mountain lake systems.

221. Snyder, Gordon G.; Haupt, Harold F.; Belt, George H. ,. Jr. Clearcutting and burning slash alter quality of stream water in northern Idaho. Ogden, Utah: USDA-Forest Service, Intermountain Forest and Range Experiment Station; 1975 Jun; Research Paper INT-168. 34 pages.

The present paper describes a stream quality study conducted on the Priest River Experimental Forest in northern Idaho. Physical and chemical components were monitored on three clearcut-burned units. Each unit and its surrounding area represented different drainage patterns. All three patterns are common in the ecosystem. Each unit was isolated from the main channel by a buffer strip of unlogged timber. The objective was threefold: to evaluate changes in the physical and chemical quality of stream water on and off the clearcut-burned units; to characterize nutrient losses from different drainage patterns; and to determine the effectiveness of buffer strips in controlling sediment and nutrient losses. This study extended for 21 months, from the fall of 1970 through the summer of 1972.

222. Solomon, Rhey. Implementing nonpoint source control: Should BMPs equal standards? In: Hook, D. D.; Lea, R., Editors. Proceedings of the symposium: The forested wetlands of the Southern United States; 1988 July 12-14; Orlando, Florida. Southeastern Forest Experiment Station, Asheville, NC: USDA Forest Service; 1989; General Technical Report SE-50: 155-162.

A nonpoint pollution control strategy is presented that emphasizes the prevention of pollution through the use of Best Management Practices (BMPs). This strategy consists of four distinct steps that comprise an iterative process: (1) Design/selection of BMPs, (2) Application of practices, (3) Monitoring, and (4) Evaluation. In this strategy, BMPs serve as a landowners performance standard while state water quality standards function as an attainment standard.

223. Sopper, W. E. Effects of Timber Harvesting and Related Management Practices on Water Quality in Forested Watersheds. Journal of Environmental Quality. 1975; 4(1): 24-29.

Undisturbed forested watersheds are generally recognized as a primary source of high-quality water. The physical and chemical nature of these waters fluctuate constantly in response to natural stresses but are most influenced by man's activities. Three major forest land management activities - timber harvesting, fertilization, and herbiciding - which may have an adverse effect on water quality are reviewed. In general, research results indicate that nutrient losses, particularly nitrogen, following forest clearcutting are small to negligible. Similarly, forest fertilization studies indicate that nitrogen concentrations in streams are not drastically increased. Large areal applications of selected herbicides in the West have demonstrated that, if carefully applied, they can be used without impairment of water quality.

224. Springer, E. P.; Coltharp, G. B. Effects of Logging Roads on Storm Hydrographs. In: Symposium on Watershed Management 1980. New York: American Society of Civil Engineers; 1980: 228-239.

Secondary road construction to expedite forest management activities may have an influence on the hydrology of streams draining forested areas. Although water quality effects have been investigated, little is known about the effects logging road construction may have on storm hydrograph quantities or timing. Construction of a mid-slope logging road around an 81.4 ha forested watershed in eastern Kentucky allowed testing of the effects of this activity on the storm hydrograph variables of peakflow rate, time to peak, quickflow volume, delayed flow volume, and total stormflow volume. The paired or control watershed technique was used for analysis. Results indicated a statistically significant decrease in dormant season peakflow rates. These decreases are thought to be partly a result of increased detention storage in the loosely packed material from the fill slope of the road and interception of subsurface stormflow or translatory flow by the road cut. Significant results were not found for any of the remaining variables, but a graph of total stormflow volume revealed a similar response to that of peakflow rate.

225. Starr, James D. Virginia non-regulatory forest water quality program. In: Fan, Shou-Shan; Kuo, Yung-Huang, editors. Proceedings of the Fifth Interagency Sedimentation Conference; 1991 March 18-21; Las Vegas, Nevada. Washington D. C.: Federal Energy Regulatory Committee; 1991: PD-16 through PD-23.

226. Stevens, P. A.; Adamson, J. K.; Anderson, M. A.; Hornung, M. Effects of clearfelling on surface water quality and site nutrient status Ecological change in the uplands. Proc. meeting held in Edinburgh, UK, 22-24 Sep. 1987 [edited by Usher, M.B.; Thompson, D.B.A.]. 1988; : 289-293.

The potential for site nutrient depletion is discussed in relation to streamwater chemistry after felling Picea sitchensis plantations at Kershope Forest, Cumbria, and at Beddgelert Forest, North Wales, and estimates of nutrient inputs/losses through a 50-yr crop rotation.

227. Stone, E. L.; Swank, W. T.; Hornbeck, J. W. Impacts of Timber Harvest and Regeneration Systems on Stream Flow and Soils in the Eastern Deciduous Region. In: Proceedings of the Fifth North American Forest Soils Conference. School of Forest resources, Fort Collins, CO; 1978: 516-534.

228. Stuart, Gordon Dunshie ,. Dale (White Mountain National Forest). Effects of Silvicultural Activities on Water Quality. Laconia, NH; 1976 Nov. 1-33.

During the last 10 years, the effects of vegetative treatment on water chemistry have been measured at a number of areas in the White Mountains. For the most part, these studies have compared stream water chemistry between control and clear cut areas. Studies have been reported on research watersheds (Pierce 1970) and on National Forest Watersheds (Pierce 1972). More recently a study has been made on a strip cut research watershed (Hornbeck 1975). Changes in water chemistry below cut areas are referred to as nutrient release or nutrient loss. Nitrate-nitrogen and calcium have been the most commonly reported nutrients. Ammonia, magnesium, potassium sodium, and sulfate have also been reported in research papers. In 1972, monitoring was started on the Upper Mill Brook Sale. This sale was typical of many on the National Forest and provided a good opportunity to monitor different treatments as there were several small streams draining the sale area. The intention was to provide data supplemental to that provided by Research. This was done by checking different areas, additional treatments, and additional nutrients.

229. Sullivan, K. A Study of Water Quality Response to Forest Management in the Middle Fork of the Santiam River, Oregon. In: Forestry Management Practices and Cumulative Effects on Water Quality and Utility. : National Council of the Paper Industry for Air and Stream Improvement; 1984; NCASI Technical Bulletin 435. 43-48.

230. Sullivan, Kathleen. Long-term patterns of water quality in a managed watershed in Oregon: 1. Suspended sediment. Water Resources Bulletin. 1985 Dec; 21(6): 977-987.

The cumulative effects of forest management activities on water quality at a downstream point were monitored from 1972-1980 during development of a watershed for timber resources. Suspended sediment concentration and turbidity were measured at two hydrologic stations which bracketed a 10-km reach of the Middle Santiam River in the Western Cascades of Oregon as it flowed through an 8000-ha block of intensity managed forest land. Slope failures often accompany road building and harvesting in steep forested watersheds and pose the most serious threat to water quality. Although 180 km of road were constructed and 3400 ha of old-growth forests were harvested from slopes averaging

over 60 percent, long-term changes in sediment yields remained undetectable during the period of measurement. The geologic characteristics of the basin and the road construction and maintenance techniques as prescribed by Oregon's forest practice regulations helped to minimize the occurrence of slope failures so that long-term changes in suspended sediment export rates did not occur. Throughout the nine-year measurement period, seven slope failures which added sediment directly to streams produced measurable short-term responses at the downstream sampling location, but these erosion events were too small and too infrequent to produce long-term changes in sediment yield from the watershed.

231. Swank, W. Stream Chemistry Responses to Disturbance. In: Ecological Studies, Volume 66: Forest Hydrology and Ecology at Coweeta. New York: Springer-Verlag; 1988: 339-357.

The vegetation on 12 watersheds at Coweeta has been altered by experimentation during the past 50 years. Disturbances include light selection cutting and logging, clearcutting without roads and no products removed, clearcutting with various methods of commercial logging, agricultural cropping, conversion of mixed hardwoods to white pine, and conversion of hardwoods to grass accompanied by applications of lime, fertilizer, and subsequent herbicide application. Also, hardwoods on two of the control watersheds have been partially defoliated by insects during the spring for varying periods of time. Two stream-gaging sites are on fourth-order streams and these larger drainages contain a combination of undisturbed and treated watersheds. A brief summary of each vegetation type represented during the period of stream chemistry record is given in Table 25.1. (see chapter 1 for details of treatments). In this chapter the objectives are (1) to characterize the chemistry of streams draining the variety of disturbed watersheds at Coweeta in terms of mean annual inorganic nutrient concentrations; (2) to compare long-term net nutrient budgets of selected disturbances with their controls; (3) to describe changes in stream chemistry in response to commercial clearcutting and succession; and (4) to examine stream chemistry responses to natural disturbances.

232. Sweeney, Bernard W. Stroud Water Research Center. Wat. Sci. Tech.. 1992; Vol. 26, No. 12: 2653-2673.

It is now clear that water and habitat quality in the coastal embayments of eastern North America are greatly affected by the quality of water and habitat in the thousands of feeder streams and rivers comprising their watershed. In this paper I suggest that the quality of streamside forests may be the single most important factor altered by humans that affects the structure and function, and ultimately water quality, of the streams providing water to the coastal embayments. I use comparative data from forested and deforested reaches of streams in a small Piedmont watershed (White Clay Creek) to illustrate the actual and/or potential effects of streamside forests on: (i) availability of habitat; (ii) the nutrient chemistry of the water; and (iii) the quantitative and qualitative nature of the primary food base (organic detritus and algae) supporting higher trophic levels in streams. Also discussed are the potential role of streamside forests in partially mitigating the flux of sediment and nutrients into aquatic ecosystems, the effects of global warming on stream temperatures, and the deleterious effects on stream organisms of the increased levels of UV radiation associated with global ozone depletion. Current methods and approaches for streamside forest restoration are presented.

233. Swift, L. W. ,. Jr. Forest Road Design to Minimize Erosion in the Southern Appalachians. In: Blackmon, B. G., ed. Proceedings of Forestry and Water Quality: A Mid-South Symposium.; 1985 May 8; Little Rock, AR. University of Arkansas; 1985: 141-151.

Excessive erosion and low serviceability of roads are continuing problems associated with forest management in the mountains of the southeastern United States. Road and erosion research at Coweeta Hydrologic Laboratory in western North Carolina dates from roadbank stabilization work in the 1930's. Emphasis has been to develop and demonstrate a low-cost, low-maintenance road design. Results cover such features as: drainage and the broad-based dip, cut-bank design and stabilization, roadbed surfacing, brush barriers and filter strips, culvert sizing, and transportation planning. Application of knowledge gained permits roads to be built and maintained at lower cost while providing practical control of sediment input to streams.

234. Swift, L. W. ,. Jr; Messer, J. B. Forest Cuttings Raise Temperatures of Small Streams in the Southern Appalachians. Journal of Soil and Water Conservation. 1971; 26: 111-116.

Stream temperatures were measured during six forest cutting treatments on small (23 to 70 acre) watersheds in the southern Appalachian Mountains. Where forest trees and all understory vegetation were completely cut, maximum stream temperatures in summer increased from the normal 66 F to 73 F or more. Some extreme treatments raised temperatures more than 12 degrees above normal. Where streambank vegetation was uncut or had regrown, summer maximums remained unchanged or declined from temperatures measured under uncut mature hardwood forest. Increases in stream temperature were judged to degrade water quality and constitute thermal pollution because, after each clearcut, water temperatures exceeded optimum levels for trout habitat.

235. Tarrant, R. F. Man-Caused Fluctuations in Quality of Water from Forested Watersheds. In: Proceedings of the Joint FAO/USSR International Symposium on Forest Influences and Watershed Management.; Moscow, USSR. : USDA Forest Service; 1970: 209-218.

Water pollution is defined as any impairment of water properties that adversely affects man directly as a living organism or indirectly through reducing the value of his physical objects or possessions or his opportunity for recreation and appreciation of nature. The changes in water quality from altered energy patterns, chemical or physical properties, or abundance of organisms therein that constitute pollution are most often the result of man's activity. Results of worldwide research indicate that man can enjoy the economic and aesthetic values afforded by forested areas and yet maintain an unpolluted supply of water. The key to producing multiple benefits from the forest, including high quality water, is the amount of care that the forest watershed manager can and will exert in all his activities. Man's actions may directly or indirectly cause changes in water quality by altering energy patterns, chemical or physical properties, or abundance of organisms therein. When such changes adversely affect man, we call the phenomenon water pollution. Effects of water pollution may be direct - a person may become ill from drinking contaminated water. More often, however, effects of water pollution are indirect - man's economic goods are lessened in value or his opportunities for recreation and appreciation of nature are impaired. But no matter whether direct or indirect, damage to man from water pollution is almost always self-inflicted. We frequently use the abstract term water quality to refer to the suitability of a water supply for some activity of man. Water of sufficiently high quality to be consumed safely by human beings might represent the upper end of the scale, but such levels of purity would not be necessary if we were determining quality standards for water to be used as an industrial coolant. Thus, we must first assume that "water quality" pertains to a degree of excellence or conformance to a standard for a specific use. Water quality standards, especially those pertaining to bacterial content, have long been used in many parts of the world. Man has been forced to arrive at a standard of safety to protect his health. Water quality standards also have been established, again through necessity, in many industries where water of poor quality may result in an unsatisfactory product. We are only now beginning to realize the urgent need for water quality standards to measure the success of forest land managers in maintaining a water supply of sufficiently high quality for the great variety of uses to which it may be put downstream. These include domestic water, recreation and aesthetics, support of fish and other aquatic life, wildlife, and agricultural and industrial uses. When we speak of the quality of water from forested watersheds, we are necessarily limited to generalizations based on our best estimates of adequate levels. In the absence of standards, we can only say that stream water quality is adequate when man is not adversely affected either directly or indirectly by its chemical, physical, or bacteriological nature, i.e., when the water is not polluted. A large part of our future task is to establish a better understanding of the water quality goals that forest watershed managers must achieve. The chemical, physical, and bacteriological nature of stream water fluctuates constantly in response both to natural forces and to man's activities. Such fluctuations are usually related to an input, either of energy, a physical substance, or a living organism. In the following discussion, we shall examine some man-caused fluctuations in major parameters of water quality in terms of such inputs.

236. Texas Forestry Association. Texas Best Management Practices for Silviculture. : Texas Forestry Association; 1989.

Texas has more than 23,000,000 acres of land that is forested. About half of this area, roughly 11.6 million acres lies in East Texas and is considered to be commercial timberland-capable of growing timber crops. East Texas timberlands are located near the borders of the neighboring states of Oklahoma, Arkansas, and Louisiana and are often referred to collectively as the "Piney Woods". Most streams that originate or course through these timberlands are sources of water supply, prime recreation, and other high quality uses. Because of this, forest management programs should incorporate adequate measures to protect water quality. The only practicable approach for reducing the nonpoint source pollution from forest activities is through the use of preventive Best Management Practices (BMP's). Planning for protection of water quality from nonpoint source pollution is provided for in the 1972 Federal Water Pollution Control Act, and as amended in the Clean Water Act of 1987. The basic goal of this law is to protect and improve the quality of the nation's waters so they remain "fishable and swimable". The purpose of this handbook is to recommend sound forest practices for Texas's climate, soils, and topography. Most Best Management Practices involve the application of conservation principles which not only minimize water pollution, but are also consistent with economic objectives. Those who carry out forest practices should voluntarily use these Best Management Practices. The progress of this program, to protect our water quality resources, will be reviewed annually. Therefore, to guarantee future flexibility in our methods of forest practices, it is important that the forest manager recognize that these freedoms could be lost if these voluntary measures fail to achieve water quality goals that have been established. Since the economy of East Texas is based on its natural resources, we must continue our good timber resource stewardship to secure this resource for ourselves and our posterity.

237. Thomas, R. B. Piecewise SALT Sampling for Estimating Suspended Sediment Yields. Pacific Southwest Forest and Range Experiment Station: USDA Forest Service; 1989; General Technical Report PSW-114. 11p.

Forest activities such as logging, road building, and mining can reduce water quality in streams and rivers. Increased sediment delivery is a possible result of such activities. Increased sediment production can have direct effect on sedimentation and fisheries, or indirect effects by acting as a vehicle for chemical pollutants. Sediment measured at a cross section in a channel system comes from dispersed sources in the watershed and follows diverse paths according to irregular and sporadic pulses in response to geologic and hydraulic factors. The sediment carried by a stream within the flow (as opposed to rolling, bouncing, or sliding along the stream bed) is termed "suspended load," and in most streams, is the majority of the load and is often monitored as an indicator of general water quality. Suspended sediment discharge cannot be measured directly, but must be calculated from measures of water discharge and suspended sediment concentration. Discharge can easily be measured by continuous mechanical or electronic recording of stage. Concentration, however, is usually measured gravimetrically on small water samples collected by hand-operated or automatic equipment. Difficult access to river stations and restrictions on laboratory processing of samples limit the number and distribution of water samples that can be collected. The basic questions when sampling suspended sediment yield are how many concentration samples to collect and when to collect them. Recent techniques allow continuous monitoring of concentration, but require expensive equipment and line electrical power. For installations having this equipment there is no problem of temporal sampling. Traditional monitoring of suspended sediment concentration is characterized by a schism between the process of temporal sampling and the methods used to calculate load. Load-calculating procedures are often based on sediment-rating curves, which have been shown to produce misleading results. While convention dictates that high flows need to be heavily sampled to obtain good estimates, the lack of well-defined temporal sampling protocols and procedures for calculating load have limited the quality of suspended load data. Probability sampling that is based on finite populations and that uses an auxiliary estimate of suspended sediment discharge to control selection of measurement times can solve all these problems. The SALT sampling scheme does this, but requires inexpensive battery-powered equipment at each stream station. Field servicing of this equipment is arduous, but reflects the validity of the conventional exhortation to sample heavily during high flows. Piecewise SALT is a modification of the original SALT procedure. It allows the user to adjust sampling to special needs such as measuring smaller storms and to limit sample collection to logistically possible regimes. Piecewise SALT also provides estimators for periods essentially disconnected from the times of station visits. Piecewise SALT retains the same desirable features of basic SALT: unbiasedness of the estimates of the total yield, estimates of variance and calculation of sample size required for specified performance.

238. Thomas, Robert B., Mathematical Statistician assigned to the Station's research unit studying the management of Pacific Coastal forests on unstable lands, and is stationed in Arcata, CA. (Pacific Southwest Forest and Range Experiment Station, Berkeley, CA). Measuring Suspended Sediment in Small Mountain Streams. Measuring Suspended Sediment in Small Mountain Streams. : Pacific Southwest Forest and Range Experiment Station; 1985 Jul; General Technical Report PSW-83.

Land management agencies are under increasing pressure to monitor the effects of their activities. One consequence has been a concern about the amount of sedimentation in streams near logging operations in forest stands. Sedimentation can adversely affect water quality as well as fish habitat. The Forest Service, U.S. Department of Agriculture has responded to this concern by increasing its collection of data on suspended sediment in streams. However, a unique set of problems exists when suspended sediment concentration is measured in forested catchments - especially those in which rain is the dominant form of precipitation. Most suspended sediment moves during infrequent high flows that collectively account for only a small portion of the measurement period. The associated high transport rates and variances dictate that most data be collected during high flows, but the infrequency and brevity of the high flow periods combined with measurement and access problems cause acute problems in collecting data. These problems will not be solved merely by increasing the amount of suspended sediment data collected. The collection process is both complex and expensive. Therefore, it is vital that such efforts yield maximum return. Often, data are collected without giving adequate thought to identifying the objectives or the administrative and technical problems that largely define what can be measured and how to measure. In such situations, analyses are difficult and interpretation ambiguous. No matter how sophisticated, analysis and interpretation can never substitute for well collected data. This report describes the administrative and technical problems that define what to measure and how to measure suspended sediment in small mountain streams. It examines the factors that govern the quality of data collected in a monitoring program, with particular attention to use of automatic pumping samplers.

239. Tiedemann, Arthur R. Stream Chemistry, Nutrient Economy, and Site Productivity Consequences of Wildland Management and Wildfire. , Baumgartner, David M. Interior West Watershed Management; 1909 Apr 8; Spokane, Washington. : Washington State University; 1981: 183-201.

The current demand for forest products has resulted in an acceleration of forest harvest activities throughout the western United States. Residue reduction and site preparation activities associated with harvest result in a redistribution of plant-contained nutrients from a relatively stable intrabiotic state with closed cycles to an unstable extrabiotic state with open cycles. Wildfire is an even more rapid and thorough mineralizing mechanism for nutrients. With both post-harvest residue treatments and wildfire, nutrients are potentially vulnerable to loss from the site via leaching and surface runoff. Movement of nutrients to aquatic systems poses a threat to water quality, and losses from the site may reduce future site productivity potential. This paper presents a review of studies throughout the semi-arid and sub-humid interior West related to chemical water quality and watershed nutrient economy responses to forest harvest, residue treatments, site preparation and wildfire. Nitrogenous and phosphorus constituents are generally at concentrations less than 1 ppm in streams from undisturbed watersheds. Nitrate-N concentrations increase following disturbance with the greatest, increase occurring after prescribed fire or wildfire. However, maximum Nitrate-N concentrations in most studies has not exceeded the recommended U.S. Environmental Protection Agency limit of 10 ppm. Phosphorus responses are variable among the few studies where this constituent was measured. In studies where increases were observed, they were not of the magnitude of Nitrate-N increases. Responses of cations such as Ca, Mg, Na, and K were also highly variable among studies. Increased moisture flux and/or increased concentrations of mineral ions result in accelerated losses of nutrients but these have generally been considered too small to affect site productivity. A more cautious interpretation is suggested in this paper based on comparisons of losses with levels of available nutrients.

240. Timber, Fish and Wildlife. Effectiveness of Washington's; Forest Practice Riparian Management Zone; Regulations for Protection of Stream Temperature. : Washington State Department of Ecology; 1992 Jul; TFW-WQ6-92-001. 59 pages, Appendices A, B, & C.

The Forest Practices Rules and Regulations contain Best Management Practices (BMP) which include requirements for Riparian Management Zones (RMZ) on certain water types affected by timber harvest activities. The purpose of this study was to test the effectiveness of the BMPs (i.e., RMZs) at achieving water quality standards for temperature. Recording thermographs were deployed upstream and downstream of thirteen RMZs statewide during the summer of 1990 to monitor stream temperature response to timber harvests. Streams and riparian zones were characterized to evaluate factors influencing the observed temperature conditions. Maximum observed water temperatures ranged from 12.8 degrees to 19.9 degrees C. Maximum water temperature change between upstream and downstream monitoring sites ranged from 0.3 degrees C to 5.2 degrees C. Definitive determinations of whether applicable water quality criteria were met or exceeded were not possible for many of the study sites due to uncertainties related to thermograph accuracy and/or representativeness of the monitoring period. Water temperature criteria were met or judged likely to be met at three of the thirteen study sites. These RMZs were considered effective. Temperature conditions at five of the thirteen study sites exceeded applicable criteria for maximum allowable temperature, with conditions at an additional three sites possibly exceeding criteria. The BMP was considered ineffective at six of the five sites where maximum allowable temperature criteria were exceeded or possibly exceeded. At two of the five sites where maximum allowable temperature criteria were exceeded, the exceedances were attributed to factors other than timber harvesting at the study site, and the BMP was considered effective. Possible exceedance of the criteria for allowable temperature change due to timber harvesting was indicated by the monitoring results at two of 13 sites. At one additional site, exceedance of the temperature change criteria was suspected based on spot field checks. The primary factors influencing BMP effectiveness appear to be site elevation, post-harvest shade levels, groundwater flux within the reach, and stream morphology. Stream modification by beavers was a significant factor influencing the effectiveness of RMZs at some sites. The proposed new TFW method for identifying temperature sensitive streams takes the most important factors into account, and is expected to correctly identify streams where enhanced RMZs are needed in a majority of cases. To optimize the effectiveness of RMZs, procedures to identify and address site specific anomalies which result in temperature sensitivities that would not be identified by the new TFW stream temperature screen and/or model should be incorporated into the BMPs.

241. Ursic, S. J. Effect of Harvesting Systems on Water Quality and Supply. In: McMillin, C. W., ed. Complete Tree Utilization of Southern Pine, Proceedings of a Symposium. New Orleans, LA: Forest Products Research Society; 1978: 103-107.

Compared to conventional harvesting, complete-tree harvesting will not significantly alter water yield. Over much of southern pinery, clearcutting can increase first-year water yields about 50 percent. Changes in physical and chemical water quality result less from removal of the biomass than from disturbances to the soil and forest floor during harvest. The leading cause of pollution of streams draining southern forest lands is mechanical site preparation, and complete-tree harvesting can reduce or even eliminate its use.

242. Ursic, S. J. Forestry Practices and the Water Resource of the Upper Coastal Plain. In: Florida's Water Resources - Implications for Forest Management. 11th Spring Symposium for the Florida Section, Society of American Foresters. : University of Florida; 1979: 83-91.

Foresters have generally been recognized as those who have protected and improved the landscape. Under their direction vast areas of abandoned farm and cutover lands have been transformed to productive thriving forests with all attendant benefits. Foremost among these benefits has been improvement in the flow and quality of water. Use of these new forests can temporarily change water quality and distribution of rainfall. But, through legislation, society is demanding that no resource be used at the expense of another. And clean water is currently receiving major emphasis. When it became apparent that controlling point sources would not make our streams clean, attention was drawn to diffuse or nonprofit sources. Because the South is mostly forest land, because forest land produces high-quality water, and because some land abuse has occurred, forestry practices have received much of that attention. My purpose is to examine how forestry practices affect water resources of the Coastal Plain's hilly sections.

243. Ursic, S. J. Harvesting Southern Forests: A Threat to Water Quality? In: Ashton, P. M.; Underwood, R. C., eds. Southern Regional Conference on Non-Point Sources of Water Pollution.; 1975 May 1; Blacksburg, VA. VPI and State University, Blacksburg, VA: Virginia Water Resources Research Center; 1975: 145-151.

Although pending regulations make pollution from forestry activities increasingly significant, the effects of harvesting on water quality are not known. In this paper I shall treat sediment as the primary pollutant and emphasize the southern pinery, which presently occupies more than half the area of southern forest lands and may cover two-thirds in less than 25 years. The South furnished almost half of the nation's wood in 1970 (U.S. Forest Service, 1973). Since wood demand is expected to double by the end of the century, supplying this need will require a 70 percent increase in annual softwood growth (Southern Forest Resource Analysis Committee, 1969). Management will intensify, and operations will become increasingly mechanized. Much private forest will be grown in short rotations, clearcut and reestablished with superior trees. Intensive culture, however, may impair southern soil and water resources. Thus a potential conflict exists between the need to increase pine production at competitive costs and the growing concern for environmental safeguards. By presenting this information, I hope to place possible pollution from harvesting into perspective and to focus on questions needing resolution before limited research resources are committed.

244. Ursic, S. J. Hydrologic Effects of Complete and Conventional Harvest of Loblolly Pine Biomass. In: Shoulders, E., ed. Proceedings of the Third Biennial Silvicultural Research Conference.; Atlanta, GA. : USDA Forest Service; 1985; General Technical Report SO-54: 565-572.

Loblolly pine plantations were established on four small calibrated catchments to determine their effect on stormflow volumes and sediment yields. They were clearfelled with minimum site disturbance during their 16th field-growing season. Harvesting treatments included two replicates of removing the above-ground biomass and of removing only the merchantable stems. Statistical comparisons of stormflow volumes as the pine developed and after harvest were based on calibrations developed with control catchments before the pine was planted. Stormflow volumes for two catchments of pine formerly in depleted hardwoods were decreased an average of 83 percent after plantation ages 12 or 13. As much as half of the decreases were retained during the 2-year postharvest period. For two catchments of pine established on more severely-eroded old fields, decreases of stormflow volumes, averaging about 50 percent after pine age 8, were largely attributed to increased interception of rainfall by the pine. After harvesting, stormflow volumes for these catchments returned to, or exceeded, preplanting levels. The erosion-history of the catchments overshadowed any differences due to the harvesting options. The developing pine on all catchments reduced sediment concentrations and yields to base levels, and postharvest increases of sediment concentrations at the gaging points were short lived. However, with increases of rates and volumes of flow after harvesting, part or all of the improvement of water quality in downstream sand channels achieved by the pine was nullified. Except for a slight increase in potassium export in stormflows, chemical water quality was unaffected. Pole-size loblolly plantations established on eroded hilly Coastal Plain sites can be harvested with minimum impact on chemical water quality and site productivity. But, such plantations, especially those planted on severely eroded old fields, are not candidates for early clearfelling where reductions of downstream sediment concentrations to improve water quality and decreases in stormflow volumes to reduce small-area floods are important.

245. Ursic, S. J. Sediment and Forestry Practices in the South. In: Fourth Federal Interagency Sedimentation Conference.; 1986 Mar 24; Las Vegas, NV. ; 1986; Volume 1: 28-37.

An average annual base rate for sediment concentrations in flows from small catchments of undisturbed southern pine is applicable to a wide diversity of southern soils and topography. Catchment studies of forestry practices have determined the range and duration of changes in sediment concentrations, and allow comparisons of alternatives. Planting pine can decrease sediment concentrations to the base rate in less than five years. Pine forests can be harvested with minimum, short-lived sediment impacts, but where channels are nonresistant, flow increases after harvesting can impair downstream water quality. Intensive mechanical site preparation can result in short-term sediment characteristics approaching those for cultivated lands. This information can help define "best management practices", the approach currently advocated to protect the quality of southern surface waters, and can help meet the mandates of the National Forest Management Act.

246. Ursic, S. J.; Esher, R. J. Influence of Small Mammals on Stormflow Responses of Pine Covered Catchments. Water Resources Bulletin. 1988; 24(1): 133-139.

The relative abundance of small mammals in five forest and cover types on the upper Coastal Plain of north Mississippi was determined. Burrowing mammals accounted for one-half of the total captures; one shrew species that accounted for over one-fourth of the total captures had a strong affinity for well-stocked pine plantations. The opportunity for detention and retention of rainfall was enhanced by burrowing activity. Reductions of stormflow volumes 12 to 15 years after replacing poor quality, upland hardwoods with loblolly pine were only partially explained by increased interception of rainfall; much of the residual reductions are postulated to be due to small mammal burrows. Small mammal activity deserves further study as an important aspect of forest land hydrology.

247. U.S. Environmental Protection Agency. Forest harvest, residue treatment, reforestation and protection of water quality. : U.S. Environmental Protection Agency; 1976; EPA 910 9-76-020.

248. USDA Dept. of Agriculture. Source Distribution of Sediment by First Approximation of Suspended (FASS) Procedure. : USDA, SCS, FS, ERS & KY Natural Resources & Environmental Protection Cabinet, KDF, KDC, KDW; 1985 Aug. 56 pages.

During 1980, concerns about water quality and soil stability resulted in a new USDA Cooperative River Basin Study in Kentucky. An initial step was the development of a plan of work to identify projects to be included in the study. Many suggestions were submitted by KNR&EPC and other state agencies. One recommendation by Kentucky's Division of Forestry and Division of Water was to identify the sources and magnitude of contributors of erosion and sediment. Additionally, it was requested that a procedure called First Approximation of Suspended Sediment (FASS) be employed. This procedure is outlined on page 4. A detailed description is given in Appendix D. The FASS procedure had been previously developed by George E. Dissmeyer, a FS Hydrologist, and utilized in river basin studies. However, its use had been limited to forest activities only, with totals used to represent all other land conditions to sediment disposition.

249. USDA Forest Service. Cumulative Impacts Analysis Water Quality and Associated Beneficial Uses. Hot Springs, AR: USDA Forest Service, Southern Region; 1990. 26 pages plus diskette.

This is a cumulative impacts model that addresses the effects of silvicultural activities on water quality and fisheries. This software is free and its distribution encouraged. This model was developed for the Ouachita National Forest in Arkansas and Oklahoma. The development of the software was paid for by the Timber, Soil, Water and Air section of the Ouachita National Forest. Keep in mind the application is specific to the physiographic zones within the Ouachita National Forest. For advice on using the model or modifying the application for other physiographic zones, contact Alan Clingenpeel, Ouachita National Forest, P.O. Box 1270, Hot Springs, AR 71902, Commercial (501) 321-5246, FTS 740-8246, DG J.Clingenpeel:R08F09A. The analysis of cumulative impacts is a requirement of the National Environmental Policy Act (NEPA). A cumulative impact analysis should consider incremental impact of actions when added to past, present and reasonably foreseeable future actions. The analysis includes all actions regardless of who undertakes the actions. Cumulative impact can result from individually minor but collectively significant actions taking place over time. Sediment is the best measure to determine the effect of management activities on water quality and its associated beneficial uses on forested lands (Coats and Miller, 1981). Sediment increases adversely affect fish productivity and diversity (Alexander and Hansen, 1986). Increases in water yields as a result of harvesting methods could also indicate cumulative impacts. However, water yield models do not characterize the impacts of all management activities such as road construction. Often the increase in water yield is less than the natural variability. Changes in water nutrients could model cumulative impacts. However, nutrient fluxes within streams as a result of management activities are minor. This model uses predicted sediment yields as the surrogate for determining cumulative impacts for water quality.

250. USDA Forest Service. Water Quality and Fisheries Resources: A Monitoring Strategy for the Ouchita National Forest, Arkansas - Oklahoma. Hot Springs, AR: USDA Forest Service, Southern Region; unk.

In terms of water quality and fisheries, state, other federal and local agencies, special interest groups (Sierra Club, Wilderness Society), the timber industry and the Ouachita National Forest have similar goals - To protect or enhance water quality and the associated beneficial uses. The following points are key to understanding the Ouachita National Forest's program: -The utilization of BMP's is a proper methodology to achieve water quality goals. -For BMP's to work an aggressive monitoring program must be pursued with an emphasis on implementation monitoring. -Effectiveness monitoring must include the inventory of the physical, chemical and biological characteristics of a stream. -The Ouachita NF actively works with other federal, state and local agencies in developing its water quality and fisheries program. -Modeling of sediment impacts on fish and aquatic invertebrates in a natural stream system is complex. Identifying trends will take a minimum of 1 to 2 years. The "ecoregion concept" is key to understanding the diverse biological populations across the Forest. -While the Ouachita NF does not have full mastery of the interactions of management activities with beneficial uses, it does recognize the potential and is taking positive steps to identify the interactions. The programs outlined in the above strategy illustrates the Ouachita NF commitment to water quality and associated beneficial uses. This is an opportunity for other groups to work with the Forest for the common goal of water quality. Actions that state, other federal and local agencies, special interest groups (Sierra Club, Wilderness Society), and the timber industry could take as proponents would be: -To publicly support the Ouachita NF's monitoring program as an effective process to protect beneficial uses. -Assist in the pursuit of funding sources to implement the monitoring program. -Recognize BMP's as an effective process of achieving water quality goals and the use of water quality standards as a tool to test the effectiveness of BMP's. -Assist in the refinement and development of predictive models. While numerous agencies and special interest groups may have differing goals and interests there is no reason the groups cannot be "Partners in Protecting Water Quality and its Beneficial Uses" with the Ouachita NF.

251. USDA Forest Service. Water Resources Analysis T-Walk: Water Quality Monitoring Field Manual and Tables. : USDA Forest Service, Region 2; 1991.

Advance Warning of existing or potential impacts on streams health. Notification and documentation of CWA related issues: 1. summary of land use & BMP impacts on CWA water quality; 2. summary of current and future (2 year) stream health; 3. expected restoration costs to recover Robust stream health; 4. a quick fix remedial action plan and follow up monitoring plan; 5. documentation of field observations. Equipmt: Waders, 5x hand level & support, survey rod, hand lens, 100' measure, insect repellant, M=calc, % clinometer, map, pins, C/F therm. Option: Camera, cord & level, trowel, snooper. This manual follows the normal steps for site analysis: begin with road & upland conditions, track the effects into the stream, & estimate current & future stream health, restoration and follow-up monitoring.

252. USDA-Forest Service. Annotated Bibliography of Research Related to the Fernow Experimental Forest. Northeastern Forest Experiment Station: USDA Forest Service; 1993 Jan; General Technical Report NE-174. 131 pages. (; NE-174).

The Fernow Experimental Forest located near Parsons, West Virginia, has a long, productive research history, as evidenced by the publications listed in this bibliography. The original 7,136-acre tract was purchased by the USDA Forest Service iin 1915. The Forest Service recognized the need for research to establish scientifically sound guidelines for managing public land and on May 28, 1934, the Fernow Experimental Forest was established through an act of Congress. Named in honor of Bernhard E. Fernow, a well-known German-born forester who pioneered scientific forestry in the United States, the forest initially comprised 3,640 acres and was expanded to about 4,700 acres in 1974. The Fernow Experimental Forest serves as a field laboratory for two research projects, one on the growth and yield of central Appalachian hardwoods, the second on protection of water resources in central Appalachian forests. Forest management research began on the Fernow in 1948 when the five 5-acre demonstration areas were installed near Big Springs Gap to evaluate the effects of different types of hardwood reproduction management. Forestry hydrology research began in 1951 when five watersheds ranging from 38 to 96 acres were instrumented to measure precipitation and streamflow. This annotated bibliography includes citations for more than 500 publications, videos, and audiovisual programs that describe 43 years of research on or related to the Fernow Experimental Forest. This research was conducted by Forest Service and cooperating scientists. The citations are arranged alphabetically by senior author, and a subject index and an index of publications by year are provided.

253. Verry, E. S., Associate Forest Hydrologist, USDA Forest Service, North Central Forest Experiment Station, Northern Conifers Lab., Grand Rapids, Minnesota. Effect of an Aspen Clearcutting on Water Yield and Quality in Northern Minnesota. Csallany, Sandor C. ,. McLaughlin, Thad G.; Striffler, William D. Watersheds in Transition; 1972 Jun 19; Ft. Collins, Colorado. : AWRA Publication; 1972: 276-284.

Water yield, water quality, and vegetation data following the first year of a complete aspen clearcutting on the upland portion of a complex, mineral-organic soil watershed are analyzed. Total streamflow increased 31 percent from June through October with no change in the composition of the water. The first spring during clearcutting, snowmelt peak flows were reduced by 35 percent. The second spring after clearcutting had been completed the previous fall, snowmelt peak flows doubled. In both years peak flows from cleared areas occurred 3 to 4 days before peak flows from forested areas. It is postulated that clearcutting does not affect peak snowmelt flows from large sustained-yield forest.

254. Verry, E. S. Forest Harvesting and Water: The Lake States Experience. Water Resources Bulletin. 1986; 22(6): 1039-1047.

The impact of forest on water has been a subject of argument for more than a century. It still is; and many studies conform that there is no single right answer in the debate. In the Lake States, clearcutting natural peatlands will not change annual streamflow nor will it seriously impact water quality if logging is done on frozen soils. However, clearcutting will cause water tables to fluctuate more, ranging from 9 cm higher to 19 cm lower than in peatlands with mature forests. Clearcutting upland hardwoods or conifers will increase annual streamflow by 9 to 20 cm 30- to 80-percent increase). Streamflow returns to preharvest levels in 12 t 15 years. Annual peak flows are at least doubled and snowmelt flood-peak increases may persist for 15 years. Water quality is not widely impacted, but operating logging equipment in stream channels will cause channel clogging by filamentous algae and loss of fish habitat. Permanent changes from forest to agricultural and urban land use on two-thirds or more of a watershed will significantly increase the size of flood peaks in the 2- to 30-year return interval storm or snowmelt.

255. Vowell, J. L. Erosion Rates and Water Quality Impacts From a Recently Established Forest Road in Oklahoma's Ouachita Mountains. In: Blackmon, B. G. Proceedings of Forestry and Water Quality: A Mid-South Symposium.; 1985 May 8; Little Rock, AR. : University of Arkansas; 1985: 152-163.

Total sediment yield was measured from four segments of a two-year-old forest road in southeast Oklahoma. Annual sediment yields ranged from 8 to 77 tons per acre, with an overall average of 41 tons per acre. Significant differences in yields between the road segments were attributed to differences in contributing area of the respective drainage outlets and to differences in road grade. Ephemeral streams adjacent to the road were sampled to determine if water quality was being influenced by road runoff. Water quality data confirmed that some sediment delivery from the road was occurring. However, maximum and mean levels of turbidity and total suspended solids were greater at sampling points above than at points below the road runoff input. The relative insignificance of road sediment delivery was attributed to dilution.

256. Walker, Jon, Forest Hydrologist (Daniel Boone NF). Beaver Creek Water Quality Monitoring Final Report. Water Quality Monitoring Report - Daniel Boone NF, Somerset Ranger District. USDA Forest Service, Daniel Boone NF; 1992 Aug.

Beaver Creek is a 9,252 acre watershed that is located on the Somerset Ranger District of the Daniel Boone National Forest in Eastern Kentucky. Only 403 acres of the headwaters of this stream are privately owned. In 1974 the United

States Congress designated the portion of the Beaver Creek watershed below the cliffline area (4,791 acres) as an Eastern Wilderness Area. As a wilderness, the area is managed to maintain the natural character in a condition similar to that which existed prior to settlement. The Forest Service, under the Organic and Wilderness Acts, is mandated to provide quality water and resources to the American public, as well as to manage wilderness areas in a pristine condition. This has been very difficult in Beaver Creek since several coal strip mines are located on the 403 acres of private land in the upstream tributaries of Cane Branch and Freeman Fork. These areas were first mined intermittently between 1955 and 1959 and due to the lack of minimg laws, very little reclamation was conducted. The area was again strip mined between 1981 and 1983. Prior to this entry, mining laws had changed and reclamation was now required. However, the companies that mined the Cane Branch area did not reclaim the land and subsequently forfeited their bond in 1984. Unfortunately, the bond was not large enough to complete the work and to this day the State has only been able to reclaim a portion of the area. Water quality has been monitored periodically in this watershed since mining first began. In 1955, the United States Geological Survey (USGS), in cooperation with the Forest Service, began an investigation to record the effects of strip mining upon as many of the affected natural resources as possible. The monitoring centered on Cane Branch since this basin was sufficiently small and was relatively undisturbed. Helton Branch, which is also a tributary of Beaver Creek, was used as a control since no mining activities were planned in this basin. The USGS investigation began just prior to the commencement of mining activities and continued until 1966, seven years after mining was completed. The project was temporarily reinstated in 1973 for one year. The effects of strip mining in this watershed were documented in a series of four reports prepared by the USGS (1963, 1964, 1970, and 1985). These reports also include many of the physical, biological and hydrologic characteristics of the Beaver Creek watershed. In 1988, water quality monitoring of this project was reinstated and continued for the next three years. The purpose of this study is threefold. First, surface water quality and aquatic biota were quantified at former USGS stations to determine if conditions had improved since the initial mining. Second, water quality was checked to determine if it was meeting State and Federal standards and to assess whether a nationally designated wilderness area was being impacted. The final objective was to compare the water quality in a tributary that had been impacted by strip mining (Cane Branch) with a tributary where mining had not occurred (Helton Branch).

257. Walsh, J. B. S. Effects of Timber Harvesting on Benthic Macroinvertebrate Populations in Southwestern Virginia. Charlottesville, VA: Virginia Department of Forestry; 1992. 53p.

Biological monitoring is relatively new to the study of water quality. Despite its recent appearance, the importance of evaluating water's ability to support the aquatic organisms which depend on it for survival and, in turn support large aquatic and nonaquatic organisms vital to the forest ecosystem, cannot be disputed. A biological health rating contributes to chemical and physical analyses, providing a complete picture of stream quality. The forest streams monitored in this study are or were healthy streams. Most began in cold, mountain springs and ran relatively undisturbed through sparsely populated, forested and agricultural land.

258. Warner, Scott A. An assessment of the effectiveness of California forest practice rules and process in protecting water quality. In: Long-term and broad-scale water quality planning and the use of environmental audits in forest management programs. New York, New York: National Council of the Paper Industry for Air and Stream Improvement; 1988 Feb; Technical Bulletin No. 541.

In 1986 and 1987, a four-member interdisciplinary team conducted a cooperative field assessment of California's Forest Practice Rules and Process and their effectiveness in protecting water quality. The study was a practical approach to a long-standing political issue: certification of the California Board of Forestry rules and Process as "Best Management Practices" by the California State Water Resources Control Board. The certification procedure was authorized under Section 208 of the 1972 Federal Clean Water Act, which requires that Best Management Practices (BMPs) be developed to effectively control sediment and waste discharge from forestry operations. Section 208 has had a major role in shaping forest practice regulations in the Northwest and in California. In California, the 208 process has been bitter and hotly contested since it began in 1977. There have been many reports and hearings over the years, and the Board of Forestry has attempted three times to gain certification by the State Water Resources Control Board. Part of the problem has been the number of regulatory boards and agencies involved, and the differences between them. There is no single authority that has total jurisdiction.

259. Washington State Forest Practices Technical Advisory Committee. Section 208. Forest Practice Demonstration Project - Logging Slash and Debris. Olympia, Washington: Water Quality Planning Office of Water Programs Dept. of Ecology; 1979 Mar; 79-5a-4.

The Washington State Forest Practices Board (FPB) is responsible for development of the Forest Practices regulations. The Department of Ecology (DOE) is responsible for preparation and implementation of the silvicultural water quality management plan required by Section 208 of Public Law 95-217, the Clean Water Act of 1977. The Forest Practices Technical Advisory Committee (FPTAC) was charged by the Forest Practices Board and DOE to investigate and report on the extent and under what conditions logging slash and debris in Type 4 waters create 1) significant water qualiy degradation inconsistent with the attainment and maintenance of fishable/swimmable water, or 2) significant potential for damage to public resources of the state. The FPTAC used a multidisciplinary subcommittee to conduct a literature review, solicit expert opinion from a variety of sources, and conduct field work. The subcommittee recommended changes in the existing Interim Slash and Debris Guidelines, originally established by the committee, and conducted additional studies on related rules and regulations. Upstream failures were the most significant cause of water quality/resource damage associated with slash and debris. Failures were associated with roads, unstable terrain, and wet weather conditions. The subcommittee concluded that the simple presence of slash and debris in Type 4 waters was not the triggering mechanism for mass movement (sluice-outs). Because a combination of natural and man-induced conditions usually must exist to trigger mass movement, the subcommittee felt that it was inappropriate to require slash and debris removal under all circumstances. Rather, removal should be based on a case-by-case evaluation. For example, it was found that in some cases sluice-out progress may be somewhat retarded by slash and debris acting in conjunction with channel alignment. In other cases, slash and debris contributed to channel scour and potential downstream blockages. Road design and location are critical factors in sluice-out initiation. Refinement of existing road construction rules should improve design and location. Proposed changes should emphasize the prevention of excessive water concentration and sidecasting on steep unstable slopes.

260. Washington State 208 Forest Practice Technical Advisory Committee. Forest practice demonstration project, logging slash and debris. : Washington State 208 Forest Practice Technical Advisory Committee, Water Quality Planning; 1979 Mar. 38 pages.

261. Webster, J. R.; Swank, W. T. Within-Stream Factors Affecting Nutrient Transport From Forested and Logged Watersheds. In: Blackmon, B. G., ed. Proceedings of Forestry and Water Quality: A Mid-South Symposium.; 1985 May 8; Little Rock, AR. : University of Arkansas; 1985: 18-41.

Nutrient concentrations in stream water are the result not only of inputs from the adjacent forest but also of instream modifications of these inputs. Important instream processes include autotrophic and heterotrophic uptake, macroinvertebrate particle generation, and retention of dissolved and particulate nutrients by woody debris. Major changes in these processes occur following forest logging. As a result of these changes, streams in the southern Appalachian Mountains may have their lowest ability to retain nutrients 20 to 30 years after logging.

262. Wigington, P. J. ,. Jr; Steinert, T. L.; Maughan, O. E. Stream Temperature Considerations of Southern Forest Management. In: Blackmon, B. G., ed. Proceedings of Forestry and Water Quality: A Mid-South Symposium. Little Rock, AR: University of Arkansas; 1985: 66-73.

A review of important research concerning the relationship between forestry activities and stream temperature is presented. Southern forest areas where vegetation management may be needed to provide desirable stream temperature regimes are summarized. Trout and smallmouth bass streams of upland areas are most likely to require special management of streamside vegetation.

263. Williams, T. M. Site Preparation on Forested Wetlands of the Southeastern Coastal Plain. In: Hook, D. D.; Lea, R., eds. Proceedings of the Symposium: The Forested Wetlands of the Southern United States.; 1988 Jul 12; Orlando, FL. Southeastern Forest Experiment Station, Asheville, NC: USDA Forest Service; 1989; General Technical Report SE-50: 67-71.

Site preparation has been applied to remove obstructions for establishment, control competition, and improve the micro-site for regeneration. Fire, mechanical, and chemical treatments have been used in pine regeneration. Bottomland hardwood regeneration is usually successful with clearcutting and elimination of non-commercial residuals. Impact studies on wet pine sites indicate site preparation can be done on these sites and cause little degradation of runoff water quality. Based on this research best management practices should concentrate on keeping equipment, fertilizer, and herbicides out of water courses. Bottomland hardwood regeneration practices are usually less intense than pine. River flooding may complicate definition of best management practices in flood plain sites.

264. Williams, T. M. Water Quality Changes on Drained Forest land. In: Research on the Effects of Forest Harvesting, Drainage, Mechanical Site Preparation, and Prescribed Fire on Water Quality. : National Council of the Paper Industry for Air and Stream Improvement; 1984; NCASI Technical Bulletin No. 442: 16-28.

265. Williams, T. M.; Askew, G. R. Water Quality Changes Associated With Forest Drainage and Pine Plantation Establishment. In: Shoulders, E., ed. Proceedings of the Third Biennial Southern Silvicultural Research Conference.; Atlanta, GA. : USDA Forest Service; 1985; General Technical Report SO-54: 536-549.

Concentrations of several dissolved constituents were measured in stormflow water draining from a 2,300 ha interstream divide in coastal South Carolina. This area contained several subwatersheds which represented phases of drainage and pine plantation establishment from an untreated hardwood area to a 15 year old pine plantation. Samples were collected from the rising and falling stages of one stormflow event of each month between January 1981 and December 1982. One liter grab samples were taken for pH, O2, NO3-N, SO4, Ca, Mg, K, and suspended sediment. Installation of new drainage produced significant increases in suspended sediment, NO3-N, SO4, Ca, and Mg concentrations. A young pine plantation, however, produced waters with concentration of hydrogen ion, NO3-N, SO4, and Mg significantly less than the untreated hardwood stand.

266. Winget, R. N.; Mangum, F. A. Biotic Condition Index: Integrated Biological, Physical, and Chemical Stream Parameters for Management. Intermountain Region, Ogden, UT: USDA Forest Service; 1979. 51p.

Many different biotic indices have been formulated to describe effects of environmental changes on biotic communities. Factors such as numbers of species, numbers of individuals, evenness, trophic habits, environmental tolerances, and niche width have all been used in various combinations. None of them have proven really effective as stream management tools. The Biotic Condition Index (BCI) developed during this study incorporates stream habitat,

water quality, and environmental tolerances of aquatic macroinvertebrate community species. It is a function of a Predicted Community Tolerance Quotient (CTQp) divided by rhe Actual Community Tolerance Quotient (CTQa). The BCI is sensitive to different types of environmental stress; it gives a linear assessment from unstressed through all levels of stress; it is applicable to many types of streams; and it evaluates a stream's condition in relation to its own potential, not that of a theoretical stream. The BCI provides the basic data for setting realistic management priorities and existing stream habitat and/or water quality management programs - providing a needed reliable biotic component.

267. Wood, J. C.; Blackburn, W. H.; Pearson, H. A.; Hunter, T. K.; Knight, R. W. Assessment of Silvicultural and Grazing Treatment Impacts on Infiltration and Runoff Water Quality of Longleaf Slash Pine Forest, Kisatchie National Forest, Louisiana. In: Ecological, Physical, and Socioeconomic Relationships Within Southern National Forests, Proceedings of the Southern Evaluation Project Workshop.; 1987 May 26; Long Beach, MS. New Orleans, LA: USDA Forest Service, Southern Forest Experiment Station; 1987; General Technical Report SO-68. 245-249.

The impact of intensive silviculture, extensive silviculture, moderate continuous livestock grazing, and no livestock grazing on infiltration and runoff water quality were evaluated using a rainfall simulator over an 11 square foot plot. Study sites were located in the Vernon District of the Kisatchie National Forest, Louisiana. Overall, infiltration and runoff water quality were significantly greater from areas under extensive silviculture and no livestock grazing than from areas under intensive silviculture and livestock grazing. Although some statistical significances were observed between treatments, differences were small and no alarming decreases in infiltration or runoff water quality resulted from any of the applied treatments. This research strongly indicates that the silvicultural and livestock grazing practices applied had minimal impacts on the prevailing climatic soil and vegetation conditions.

268. Yee, Carlton S.; Roelofs, Terry D. Planning forest roads to protect salmonid habitat. William R. Meehan, technical editor. Portland, Oregon: USDA-Forest Service, Pacific Northwest Forest and Range Experiment Station; 1980; General Technical Report PNW-109. (Influence of forest and rangeland management on anadromous fish habitat in western North America (no. 4)).

A forest transportation system can have significant effects on anadromous fish and their habitats. Often, the effects have been adverse. Examples of adverse changes caused by forest roads, log sorting, and log-storage areas include increased sediment and organic debris in streams, changes in water quality and quantity, formation of physical barriers to the movement of adult and juvenile fish, and increased human access to previously remote or isolated areas. This report describes how elements of a forest transportation system cause environmental changes that affect anadromous fish habitat and provides guidelines for the design, construction, and maintenance of these facilities to minimize adverse effects. In the first publication in this series, Reiser and Bjornn have discussed habitat requirements of anadromous salmonids; we will limit our discussion to effects on the fish and their habitats that directly stem from forest roads, log sorting, and log-storage areas.

269. Ziemer, R. R.; Lewis, J.; Lisle, T. E.; Rice, R. M. (USDA Forest Service, Arcata, CA). Long-Term Sedimentation Effects of Different Patterns of Timber Harvesting. in: Peters, N. E.; Walling, D. E. Sediment and Stream Water Quality in a Changing Environment: Trends and Explanation (Proceedings of the Vienna Symposum); 1991 Aug. ; IAHS Publication No. 203: 143-150.

It is impractical to address the long-term effect of forest management strategies on erosion, sedimentation, and the resultant damage to fish habitat experimentally because to do so would require studying large watersheds for a century or more. Monte Carlo simulations were conducted on three hypothetical 10 000 ha, fifth-order forested watersheds.

One watershed was left undisturbed, one was completely clearcut and roaded in a decade, and one was cut at the rate of 1% each year. Each cutting strategy was repeated in succeeding centuries.

Abstracted Articles Referencing "Forestry" and "Mass Wasting"

Compiled by Samuel H. Austin

270. Bell, K. L.; Bliss, L. C. Alpine Disturbance Studies: Olympic National Park. Biological Conservation. 1973; 5(1): 25-32.

Measurements of downslope rock-creep, of the slow rate of plant establishment on alpine and subalpine road-cuts, and of the reduction in plant cover and plant production in two alpine plant communities, illustrate the degree of disturbance that can occur. The development of large trails or roads should not be permitted in areas of such active downslope rock movement, because of the natural rate of mass-wasting. If more people are to visit and enjoy the alpine communities, asphalt paths to confine their walking are desirable, for trampling experiments showed that plant cover and plant production were rapidly reduced in even one season of light use. Recovery during the following year was, however, quite rapid - especially in the snow-bank community. Different alpine and subalpine habitats have different sensitivities to disturbance, and any plans for increased human use must incorporate this kind of information.

271. Coats, Robert; Collins, Laurel. Effects of Silviculture Activities on Site Quality: A Cautionary Review. : California Department of Forestry; 1981 Oct; CDF 7690-130-0121. 33 pages.

Timber harvest activities have been shown to alter many of the processes that influence the productivity of a forest site. Among the mechanisms involved in possible productivity losses are: 1) export of nutrients in harvested material, 2) leaching loss of nutrients, 3) loss of nitrogen and soil organic matter by slash burning and accelerated decomposition, 4) soil and nutrient loss by surface erosion and mass wasting, 5) soil compaction and disturbance by heavy equipment. The most serious and significant of these are probably the losses associated with improper burning, losses by surface erosion and mass wasting, and soil compaction. Natural processes and mitigating measures are able in some degree to compensate for the deleterious effects of timber harvest activities. On much of the forest land in California, current practices are not likely to result in long-term loss of site productivity. There are sites, however, where silvicultural activities probably are resulting in a loss of site quality, and where current practices should be reexamined. There are also sites that can probably tolerate present practices but where intensive utilization and short rotations will result in a decline in the long run. Disruption of nutrient cycles in boreal forests and acceleration of erosion and mass wasting in the Klamath Mountains are two problem areas that deserve more attention. Maintaining site productivity in the long run requires careful site-specific planning based on detailed knowledge of soil characterisitics. In some instances, it requires higher capital and operating costs. Among the steps recommended to increase protection of forest soil resources are: 1) increased collection and analysis of basic data on forest soils, 2) increased emphasis on forest soils in the education of professional foresters, and 3) development and revision of standards and restrictions that may be applied to timber harvest and site preparation on steep and unstable hillslopes.

272. Guy, H. P. Fluvial Sediment Concepts. In: Techniques of Water Resources Investigations of the United States Geological Survey. US Government Printing Office: Washington DC; 1970; Applications of Hydraulics(Book 3): Chapter C1.

This report is the first of a series concerned with the measurement of and recording of information about fluvial sediment and with related environmental data needed to maintain and improve basic sediment knowledge. Concepts presented in this report involve (1) the physical characteristics of sediment which include aspects relative to weathering, soils, resistance to erosion, and particle size, (2) sediment erosion, transport, and deposition characteristics, which include aspects relative to fine sediment and overland flow, coarse sediment and streamflow, variations in stream sediment concentration, deposition, and denudation, (3) geomorphic considerations, which include aspects relative to the drainage basin, mass wasting, and channel properties, (4) economic aspects, and (5) data needs and program objectives to be attained through the use of several kinds of sediment records.

273. Hogan, D. L. Channel morphology of unlogged, logged, and debris torrented streams in the Queen Charlotte Islands. Land Management Report, Ministry of Forests and Lands, British Columbia. 1986; no. 49.

This study compares the morphology of coastal, gravel-bed streams in two logged, one logged and debris torrented, and two unlogged watersheds in the Queen Charlotte Islands. The influence of both logging and direct mass wasting events on channel morphology and, consequently, on the in-stream physical habitat of salmonids is quantified. The comparison also provides a basis for determining habitat rehabilitation criteria for damaged channels. Pools and riffles are discussed in detail. Longitudinal profiles of long channel segments indicated that channels in watersheds either logged to the channel banks by old techniques (but not torrented), or logged by more recent methods (but which have experienced direct mass wastage events) result in reduced pool-to-pool spacings, increased riffle heights, and altered pool depths. Increases in stored sediment volumes produce proportionally larger riffles and smaller pools, thus reducing available rearing habitat. No significant differences in pool and riffle characteristics were found between unlogged watersheds and those logged by contemporary techniques and not torrented. Large organic debris (LOD) appeared to be a major influence on stream morphology. A comparison of reaches indicated that LOD characteristics were altered in older logged and torrented channels, including a shift in the LOD size distribution, with smaller in-channel material being more prevalent. Orientation of material was also altered: more LOD lay parallel to the flow direction, as opposed to the more common diagonal orientation found in unlogged and non-torrented channels. This shift in orientation was responsible for a reduction in channel width and depth variability, reduced sediment texture variability, fewer cut banks, smaller pool areas, and decreased channel stability. These changes resulted in reduced habitat diversity and quality. No morphological differences were detected between unlogged and recently logged (non-mass wasted) reaches. Results of this study suggest that the architecture of unlogged channels can be duplicated to help rehabilitate streams damaged by mass wasting. LOD should play a major role in rehabilitation, and several recommendations for channel restoration are made.

274. Ice, George G. Landslide inventories, current research and pending forest practice act rule changes for mass wasting associated with forest management practices. In: Blosser, Russell O., Technical Editor. Forest Management Practices and Natural Events - Their Relation to Landslides and Water Quality Protection. New York, New York: National Council of the Paper Industry for Air and Stream Improvement; 1983 Jun(NCASI Technical Bulletin No. 401). 20 pages.

Landslides are a natural erosional process. However, inventories of landslides have shown that the rate of occurrence of landslides can be influenced by forest practices. Recently Oregon, Washington and California have been addressing new controls for mass wasting from forest lands (1-3). This paper will review emerging changes in the Oregon Forest Practice Rules and discuss how existing landslide inventories are helping to identify appropriate practices, questions being raised about management options, and current research which could provide answers to questions about landslides in managed forests.

275. Ice, George G. (NCASI). Programs Dealing with Forest Management and Water Quality. in: Research on the Effects of Mass Wasting of Forest Lands on Water Quality and the Impact of Sediment on Aquatic Organisms. New York, NY: NCASI; 1981 Apr; TB No. 344. 1-56.

For the past three years the Southern and West Coast Regional meetings have featured one or more sessions covering research and field investigations on the impact of forestry management practices on receiving water quality and utility. This technical bulletin is an assembly of the papers and abstracts of presentations made at the West Coast Regional Meeting in 1981 at sessions arranged by Dr. George G. Ice, Research Hydrologist at the West Coast Regional Center. The program featured four papers on the relationship of forestry management practices and mass movement of soils. James Sachet, Washington Department of Ecology; Robert R. Ziemer, USDA Forest Service, Dale McGreer, and James McNutt, Potlatch Corporation; and George G. Ice participated in this segment of the program. William L. Jackson and Robert L. Beschta, Oregon State University, presented a progress report on the forest products industry funded project underway at the University on the movement of sediment in stream systems. The subject of aquatic biology was covered by Dr. E. Salo, University of Washington, who described elements of an extensive program underway at the University of Washington on the impact of sediments from logging-associated activities on the fishery resource. Charles Hawkins, Oregon State University, described the relative effects of sediment and canopy removal on stream communities. Dr. George G. Ice presented a summary of ongoing research programs and information needs relating to forestry management practices and water quality in the Northwest.

276. Ice, George G. Research on the effects of mass wasting of forest lands on water quality and the impact of sediment on aquatic organisms. : National Council of the Paper Industry for Air and Stream Improvement; 1981; Technical Bulletin No. 344.

277. Keller, E. A.; Swanson, F. J. Effects of Large Organic Material on Channel Form and Fluvial Processes. Earth surface processes. 1978; 4: 361-380.

Stream channel development in forested areas is profoundly influenced by large organic debris (logs, limbs and rootwads greater that 10 cm in diameter) in the channels. In low gradient meandering streams large organic debris enters the channel through bank erosion, mass wasting, blowdown, and collapse of trees due to ice loading. In small streams large organic debris may locally influence channel morphology and sediment transport processes because the stream may not have the competency to redistribute the debris. In larger streams flowing water may move large organic debris, concentrating it into distinct accumulations (debris jams). Organic debris may greatly affect channel form and process by: increasing or decreasing stability of stream banks; influencing development of midchannel bars and short braided reaches; and facilitating, with other favourable circumstances, development of meander cutoffs. In steep gradient mountain streams organic debris may enter the channel by all the proceses mentioned for low gradient streams. In addition, considerable debris may also enter the channel by way of debris avalanches or debris torrents. In small to intermediate size mountain streams with steep valley walls and little or no floodplain or flat valley floor, the effects of large organic debris on the fluvial processes and channel form may be very significant. Debris jams may locally accelerate or retard channel bed and bank erosion and/or deposition; create sites for significant sediment storage; and produce a stepped channel profile, herein referred to as "organic-stepping", which provides for variable channel morphology and flow conditions. The effect of live or dead trees anchored by rootwads into the stream bank may not only greatly retard bank erosion but also influence channel width and the development of small scour holes along the channel beneath tree roots. Once trees fall into the stream, their influence on the channel form and process may be quite different than when they were defending the banks, and, depending on the size of the debris, size of the stream, and many other factors, their effects range from insignificant to very important.

278. Mersereau, R. C.; Dyrness, C. T. Accelerated Mass Wasting After Logging and Slash Burning in Western Oregon. Journal of Soil and Water Conservation. 1972; 27(3): 112-114.

Mersereau, R. C.; Dyrness, C. T. Accelerated mass wasting after logging and slash burning in western Oregon. Journal of Soil and Water Conservation. 1972: 112-114.
Note: have it.
Clearcut logging and slash burning in a steel 237-acre watershed in western Oregon resulted in increased rates of soil movement, especially on slopes unprotected by organic debris. During the first growing season after burning, soil movement, which largely occurred as dry ravel, was most pronounced on 80-percent slopes (versus 60-percent), on south aspects (versus north), and in areas having little plant cover (versus well-vegetated areas). By the second growing season after burning, rapid invasion by vegetation essentially halted soil movement on all alopes except extremely stony talus areas.

279. Miller, A. J. Fluvial Response to Debris Associated With Mass Wasting During Extreme Floods. Geology. 1990; 18(7): 599-602.

Evolution of channels and bottomlands in mountain valleys of the central Appalachians is strongly influenced by debris supplied to stream channels from mass wasting during extreme storms. The type of change observed varies with basin scale and storm characteristics. Along channels receiving coarse sediment from debris avalanches or debris flows during Hurricane Camille in 1969, pure scour occurred in drainage areas less than 1 km2 and gradients steeper than 0.1; in Hurricane Camille and in the June 1949 storm, mixed erosion and deposition with continuous reworking of the valley floor was observed along streams with drainage areas up to 65 km2. In basins larger than 100 km2, valley-floor reworking associated with influx of debris during both storms was localized and discontinuous. In the South Branch Potomac River basin in West Virginia, intense precipitation within a small contributing area generated scores of debris slides and avalanches in June 1949; debris transported by tributaries to main valleys exceeded the competence of the larger channels and formed new bottomland. Long-duration moderate-intensity precipitation in November 1985 generated fewer debris avalanches. Flood peaks associated with a larger contributng area along the main valleys were 80% to 190% larger than in 1949 and caused extensive channel and flood-plain erosion, including truncation and removal of 1949 deposits. At some locations relict debris deposits may have influenced hydraulic conditions and affected patterns of erosion and deposition during the 1985 storm. Sequential occurrence of extreme storms with different hydrologic characteristics creates a bottomland mosaic of surfaces with varying elevations and textures.

280. Montgomery, David R.; Buffington, John M. (Dept. of Geological Sciences and Quaternary Rewearch Center, University of Washington, Seattle, WA). Channel Classification, Prediction of Channel Response, and Assessment of Channel Condition. DRAFT report prepared for the SAHMW committee of the Washington State Timber/Fish/Wildlife Agreement. ; 1993 Mar 24. 83 pages (22 figures).

A process-based landscape and channel classification is proposed as a framework for assessing watershed response to natural and anthropogenic environmental change. Our proposed classification is based on a hierarchy of process-regimes at several spatial scales: i) geomorphic province, ii) watershed, iii) valley segment, iv) channel reach, and v) channel unit. The geomorphic province level identifies watersheds developed in similar materials, topography, and climates, reflecting comparable hydrologic, erosional, and tectonic processes. The watershed level identifies hillslopes and valleys, defining fundamental differences in transport processes within a contiguous drainage basin. Valley segment morphologies further distinguish transport processes and general relations between transport capacity and sediment supply of both channeled and unchanneled valleys. At the reach level, distinct morphologies may be identified based on sediment transport characteristics, channel roughness elements, and bedforms. Channel reaches, in turn, are composed of finer-scale channel units. Within this framework, our discussion focuses mainly on the valley segment and channel reach levels. Valley morphology and sediment transport characteristics define colluvial, alluvial, and bedrock valley segments. Unchanneled valleys (hollows) are characterized by a lack of fluvial processes. Channeled colluvial valleys are those in which fluvial sediment transport maintains a channel, but in which the transport is insufficient to mobilize all of the colluvium delivered from the surrounding hillslopes. In mountain drainage basins, colluvial valleys are dominantly carved by mass wasting processes. Alluvial valleys contain predominantly alluvial fills and are characterized by fluvial transport of sediment over a variety of alluvial bed morphologies. Alluvial valley segments may be either confined or unconfined, reflecting general relations between transport capacity and sediment supply. Bedrock valley segments lack a continuous alluvial cover due to high transport capacities. Valley morphology generally reflects the relation between sediment supply and transport capacity. At the channel reach-level of the classification, bed morphology is coupled with both the potential for debris flow impacts and the role of large woody debris loading to characterize channel processes and provide a framework within which to examine potential channel response. Colluvial and bedrock channels occupy corresponding valley segments, but we recognize six alluvial channel types: regime, braided, pool-riffle, plane bed, step-pool, and cascade. We hypothesize that observed systematic and local downstream changes in alluvial channel morphology and channel roughness correlate with changes in channel slope, sediment supply (size and amount of material available for transport) and transport capacity (a function of the available shear stress). These differences provide the basis for interpreting the potential response of different areas of the channel network to perturbation. In general, steep alluvial channels (step-pool and cascade) tend to maintain their morphology while transmitting increased sediment loads. In contrast, low-gradient channels (regime and pool-riffle) typically respond to increased sediment loads through morphologic adjustment. In essence, steep channels effectively act as sediment delivery conduits connecting zones of sediment production on hillslopes to downslope low-gradient channels. Such distinctions allow recognition of source, transport, and response reaches. Channel morphology thus reflects the local and watershed-integrated processes influencing sediment supply and transport capacity. Evaluation of channel response potential within the context of morphologically-characteristic processes allows distinction of different response potential for different portions of a channel network. While the proposed channel classification provides insight into potential channel response that can guide impact assessment, changes in sediment supply and transport capacity may result in either similar or opposing effects. This highlights the reality that changes in discharge and sediment supply cannot be examined in isolation; both need to be considered when assessing either watershed conditions or the potential for future impacts. In particular, it is necessary to focus on aspects of channel morphology and dynamics that are sensitive indicators of perturbation and to consider the specific channel type and position in the channel network. A number of quantitative and qualitative approaches provide insight into evaluating watershed impacts and predicting potential responses to continuing or anticipated watershed disturbance.

281. Poulin, V. A. A research approach to solving fish/forestry interactions in relation to mass wasting on the Queen Charlotte Islands. Fish Forestry Interaction Program, Vancouver, BC: Ministry of Forests; 1984; Land Management Report No. 27. 16p.

A description is given of the interdisciplinary approach being used to assess the effect of mass wasting on fish habitat and forest land and to determine the best methods for logging steep slopes and rehabilitating damaged stream and forest sites in this region of British Columbia heavily dependent on both fish and logging.

282. Rice, R. M.; Krammes, J. S. Mass-Wasting Processes in Watershed Management. In: Proceedings of the Symposium on Interdisciplinary Aspects of Watershed Management.; Bozeman, MT. : American Society of Civil Engineers; 1971: 231-259.

Erosion by mass-wasting processes is often underestimated because some processes, such as soil creep and dry creep, are unspectacular and others, landslides, occur infrequently. Actually, in mountainous regions, these forms of erosion make up a large proportion of the total erosion. Mass movements are especially sensitive to disturbances by man such as road building, logging, and vegetative manipulation. The interactions between road location and slope stability are discussed. Quantitative estimates of the erosional costs of conversion from brush to grass in southern California are presented. Since existing terrain features indicate the likelihood of slope failure, the erosional cost of work likely to decrease slope stability can be estimated fairly well in advance.

283. Sidle, Roy C. Slope stability on forest land. : Pacific Northwest Extension; 1980 Aug; PNW 209. 23 pages.

The dominant erosional process on forest land in the Pacific Northwest is mass soil movement. Mass soil movements, which commonly occur as landslides, involve the transport of large quantities of soil and debris, primarily by gravity. This is in contrast to the often more visible process of surface erosion, in which individual soil particles are detached and transported downslope by water. While surface erosion may be a significant sediment contributor to streams from localized sites such as cut banks and road surfaces, sedimentation due to various mass wasting processes is much greater on the forested hillslopes of the Pactific Northwest region. This publication deals with basic causes of slope failures, and the impacts of road construction, timber harvesting, and slash burning, with emphasis on control measures to reduce landslide hazards.

284. Swanston, D. N. Mass Wasting in Coastal Alaska. Pacific Northwest Forest and Range Experiment Station: USDA Forest Service; 1969; Research Paper PNW-83. 15p.

An understanding of erosion processes involving the downslope movement of earth materials is essential to the forest-land manager in Alaska. This has become increasingly clear in recent years with apparent acceleration of slope erosion following large-scale clearcutting of steep, timbered slopes in southeast Alaska. Erosion occurs primarily as soil mass movements associated with oversteepened slopes and high soil-water levels. In 1961, a marked increase in slide activity associated with a period of high rainfall was observed in a number of recently logged areas. These observations brought about a survey of potential sliding in these areas. As a result of this survey, the principal sliding phenomena were identified and classified, and major factors contributing to their occurrence and distribution were evaluated (Bishop and Stevens 1964). Later work has concentrated on detailed investigations of landslide distribution, processes of movement, and factors affecting occurrence. This paper summarizes and interprets the accumulated data and knowledge about slope erosion in southeast Alaska, particularly in relation to recently logged areas, with general suggestions and guidelines for prediction and control.

285. Tripp, D. B.; Poulin, V. A. The effects of logging and mass wasting on salmonid spawning habitat in streams on the Queen Charlotte Islands. Land Management Report, Ministry of Forests and Lands, British Columbia. 1986; No. 50.

Results are given of surveys of gravel composition of streams in logged and unlogged areas, affected by varying degrees of mass wasting, and of the amount of gravel scour in 12 streams in logged areas. Logging alone increased fine sediment in streams as much as or more than mass wasting upstream. The estimated decline in coho [Oncorhynchus kisutch] egg to fry survival due to mass wasting and/or logging-related increases in sediment was 15-20%. In logged reaches directly affected by mass wasting, or in streams where bedloads were excessive because of mass wasting upstream, estimated egg losses due to scouring were 66-86% for chum salmon [Oncorhynchus keta] and 45-70% for coho salmon. In logged, but otherwise stable reaches with no recent mass wasting, scour-related egg losses were 2-14% for chum salmon and 0-4% for coho salmon.

286. Ziemer, R. R.; Lewis, J.; Rice, R. M.; Lisle, T. E. Modeling the Cumulative Watershed Effects of Forest Management Strategies. Journal of Environmental Quality. 1991; 20: 36-42.

There is an increasing concern over the possibility of adverse cumulative watershed effects from intensive forest management. It is impractical to address many aspects of the problem experimentally because to do so would require studying large watersheds for 100yr or more. One such aspect is the long-term effect of forest management strategies on erosion and sedimentation and the resultant damage to fish habitat. Is dispersing activities in time and space an effective way to minimize cumulative sedimentation effects? To address this problem, Monte Carlo simulations were conducted on four hypothetical 10,000-ha fifth-order forested watersheds: One watershed was left undisturbed, one was completely clearcut and roaded in 10 yr, with cutting starting at the head of the watershed and progressing toward the mouth, another was cut at the rate of 1% each year, with individual cut areas being widely dispersed throughout the watershed. These cutting patterns were repeated in succeeding centuries, rebuilding one-third of the road network every 100 yr. The parameters governing the simulations were based on recent data from coastal Oregon and northwestern California. Mass wasting, the most important source of sediment in that environment, was the only hillslope process modeled. The simulation results suggest that (i) the greatest differences between management strategies appeared in the first 100 yr and were related primarily to the rate of treatment. By the second 100 yr, when all the watersheds had been treated, the principal difference between logging strategies was the timing of impacts. (ii) Dispersing harvest units did not significantly reduce cumulative effects. (iii) The frequency of bed elevation changes between 1 and 4 cm is dramatically increased by logging.

287. Ziemer, R. R.; Lewis, J.; Rice, R. M.; Lisle, T. E. Modeling the cumulative watershed effects of forest management strategies. Journal of environmental quality. 1991; 20(1): 36-42.

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